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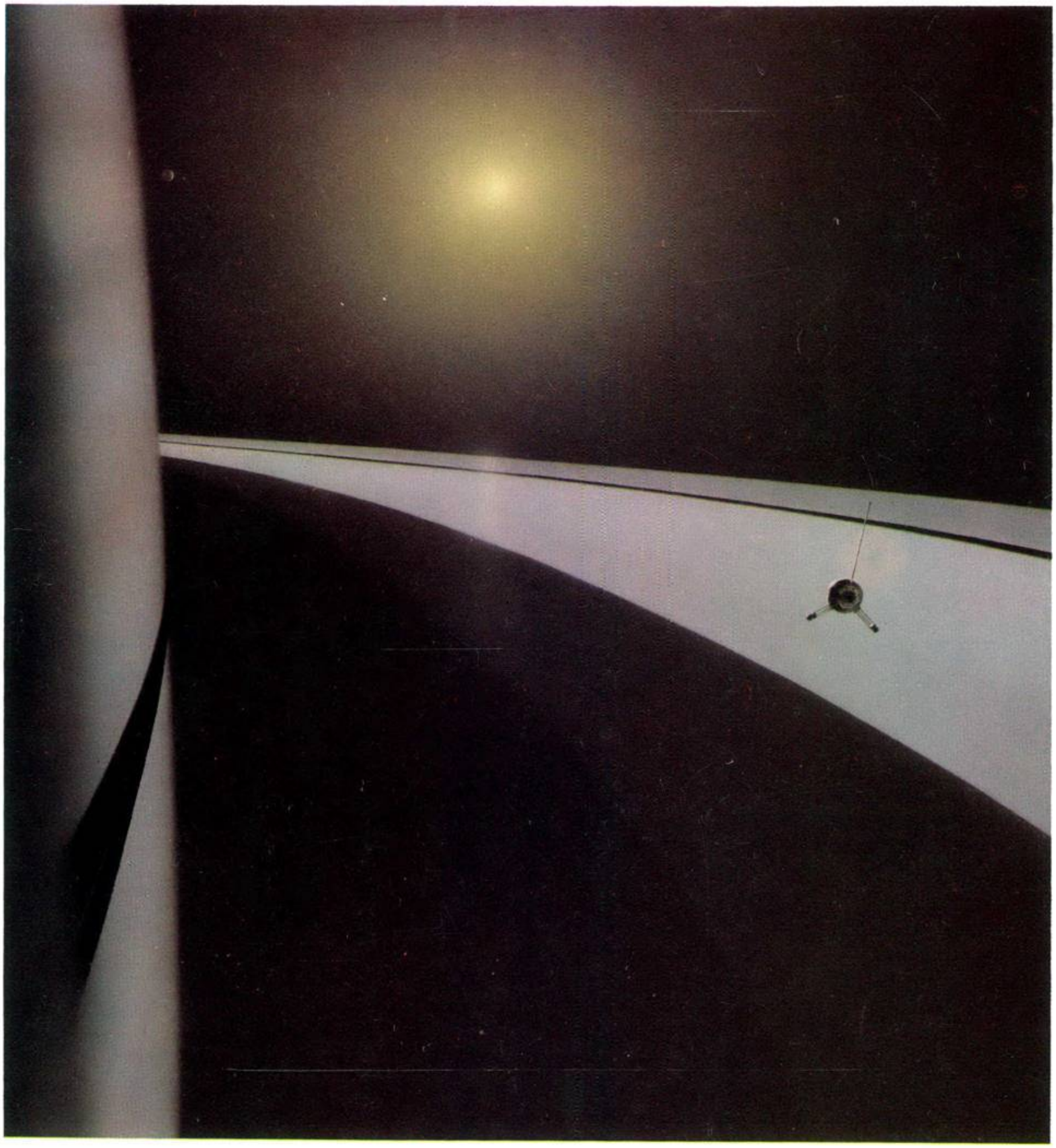

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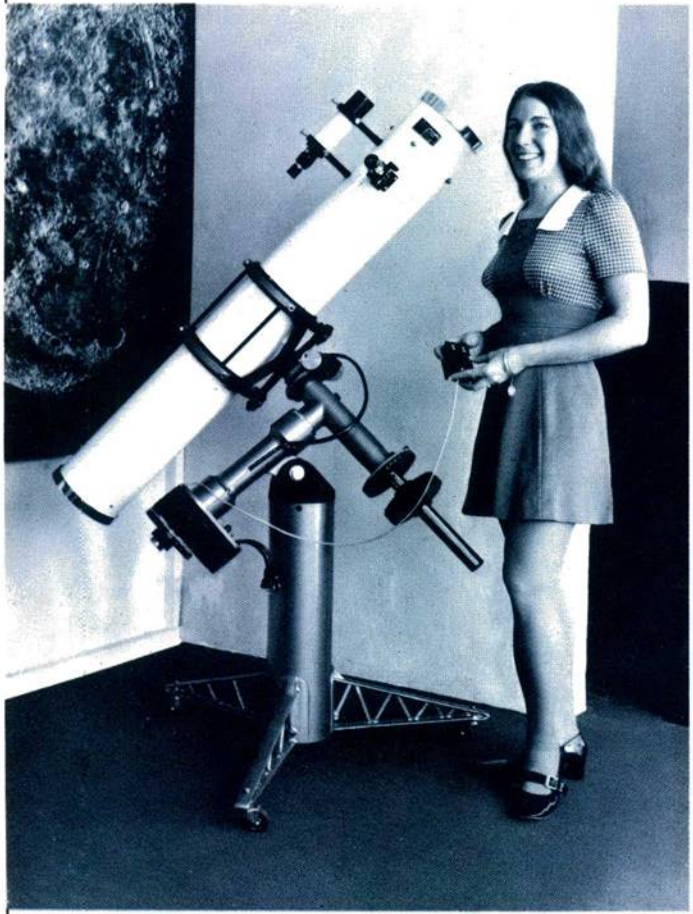

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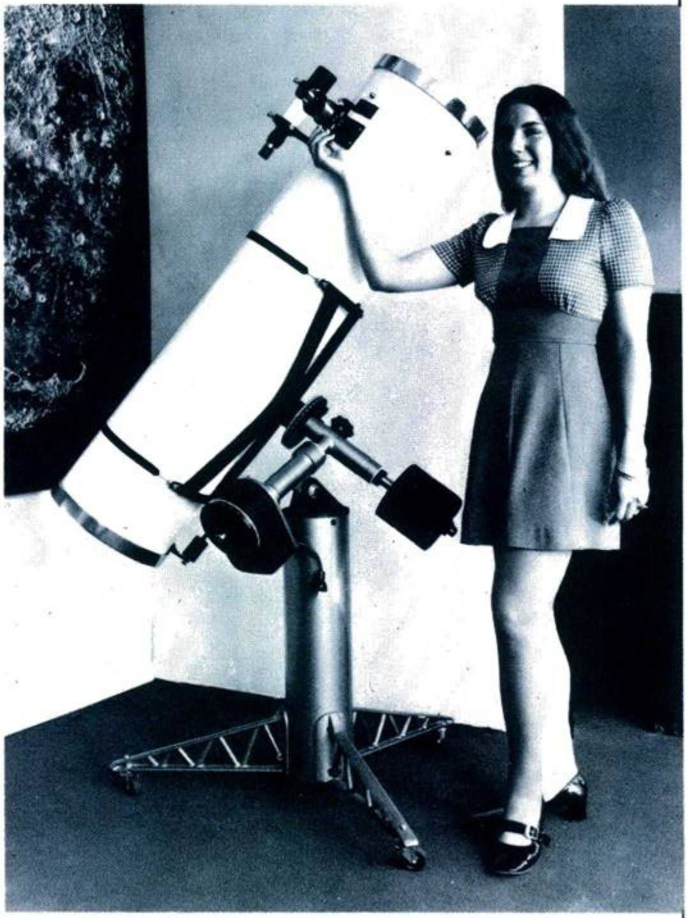

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ASTRONOMY

The World's Most Beautiful Astronomy Magazine

March 1975 Vol. 3, No. 3

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Cover
Artwork by Adolf Schaller
In September 1979 Pioneer 11 will pass inside the inner edge of Saturn's rings only a few thousand miles above the frosty clouds of the second largest planet. If successful, this will mark the first spacecraft exploration of Saturn and its moons. One of those moons, Titan, will be briefly examined as Pioneer hurtles away from Saturn. Future exploration of Saturn was detailed in major articles in the January and February 1975 issues; this month Titan is examined.

Published monthly by AstroMedia Corp., 757 North Broadway, Suite 204, Milwaukee, Wisconsin 53202. Telephone (414) 276-2689. Copyright ©1975 by AstroMedia Corp., all rights reserved. No part of this issue may be reproduced by any mechanical, photographic or electronic process, or otherwise copied for public or private use without written permission of the publisher.

Second class postage paid at Milwaukee, Wisconsin.

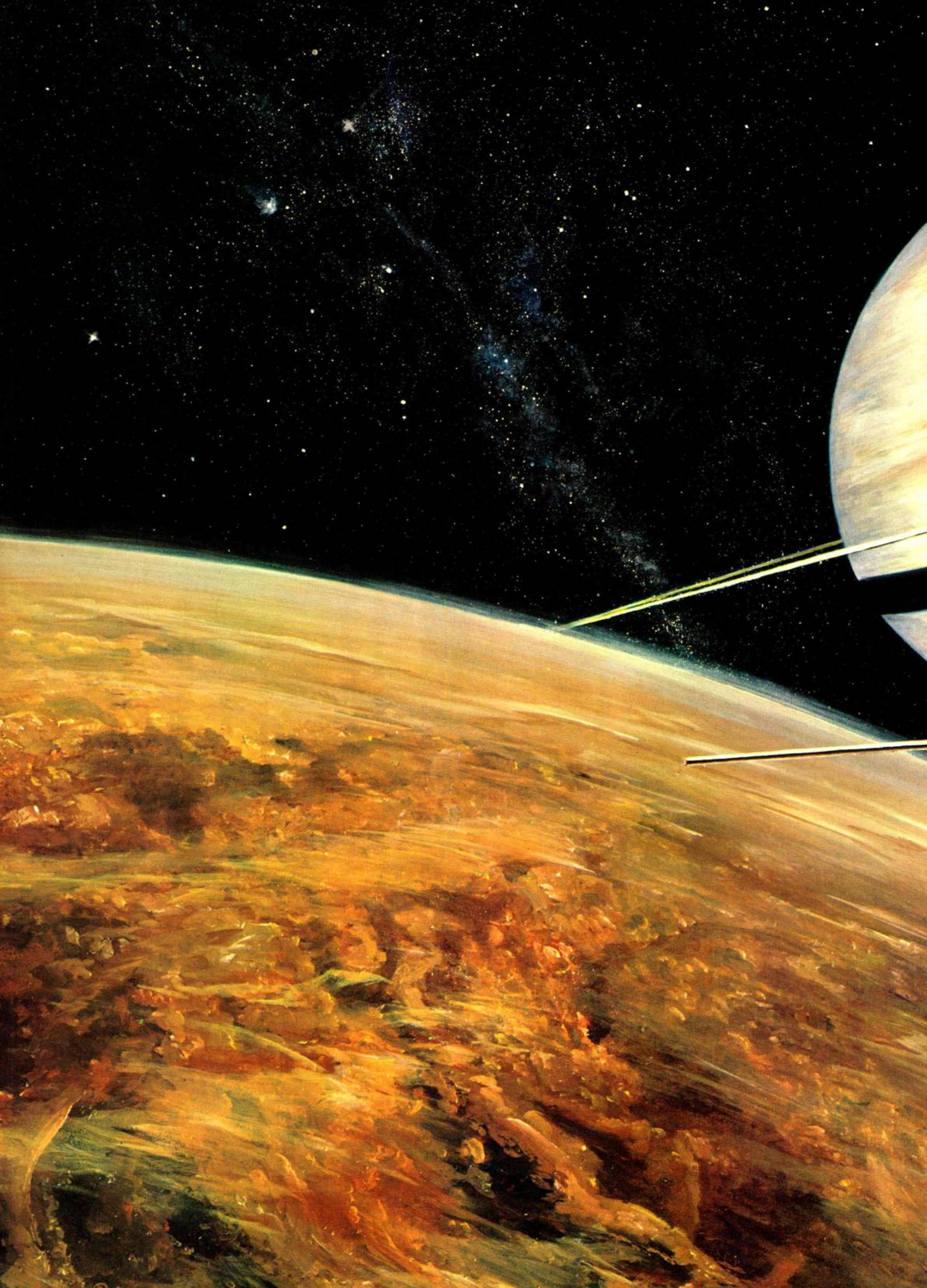
Direct all subscription correspondence, new subscriptions, changes of address and complaints to ASTRONOMY, Circulation Services, 640 North LaSalle Street, 6th Floor, Chicago, Illinois 60610. Allow six to eight weeks for address change to take effect.

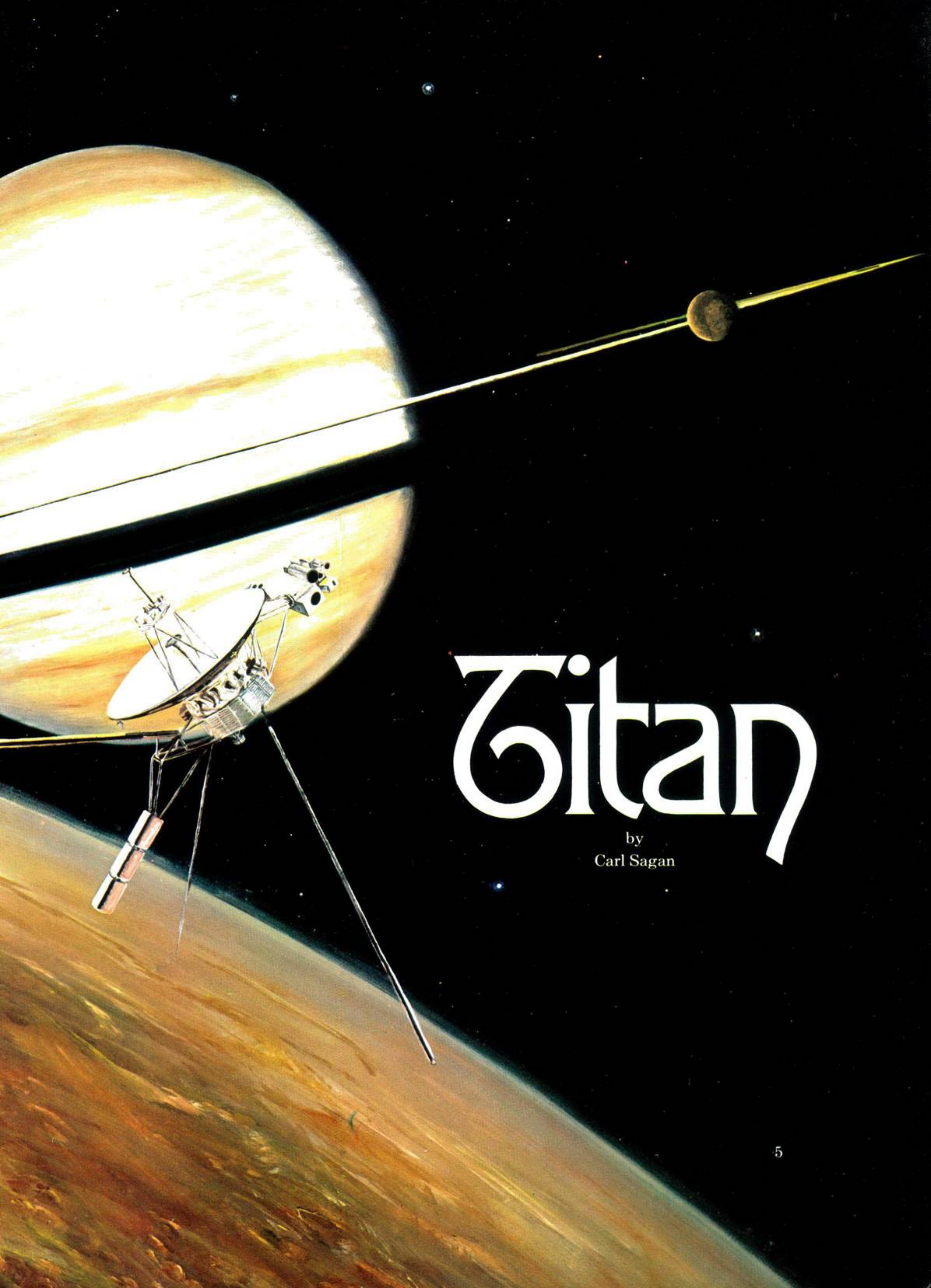
Cover price, $1.50. Subscription price: 1 year, $12.00; 2 years, $22.00; 3 years, $30.00. Canada and Mexico: add $3.00 per year. All other foreign: add $6.00 per year.

POSTMASTER: When undeliverable, send form 3579 to publisher.

Typesetting by Grafilm, Inc., Milwaukee, Wisconsin 53210; Separations prepared by American Color Systems, New Berlin, Wisconsin 53005; Printed by E. F. Schmidt Co., Menomonee Falls, Wisconsin 53051.

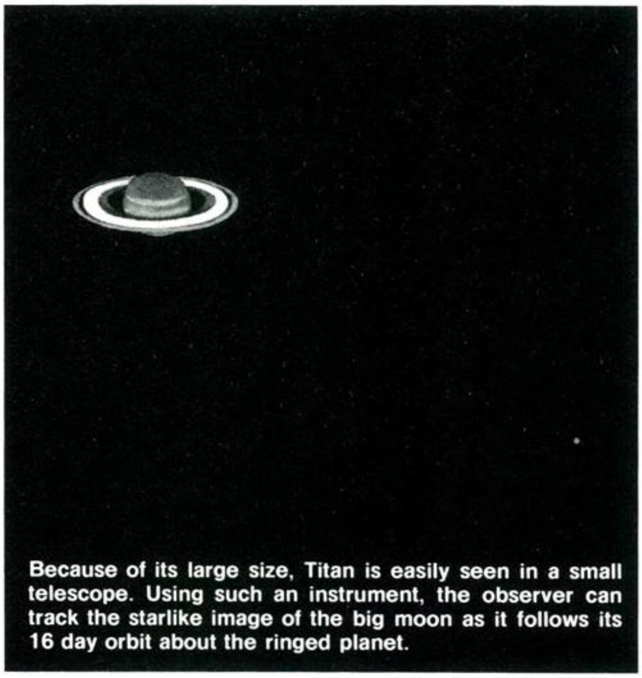
Due to the limited availability of back issues, new subscriptions must start with the most current month's issue. If you wish to order back issues it is advisable to inquire first before placing an order.





Titan

by
Carl Sagan



Because of its large size, Titan is easily seen in a small telescope. Using such an instrument, the observer can track the starlike image of the big moon as it follows its 16 day orbit about the ringed planet.

Artwork by Victor Costanzo

Titan is not a household word, or world. We do not usually think of it when we run through a list of familiar objects in the solar system. But in the last few years this satellite of Saturn has emerged as a place of extraordinary interest and prime significance for future exploration. Our most recent studies of Titan have revealed that it has an atmosphere more like Earth's — at least in terms of density — than any other object in the solar system. This fact alone gives it new significance as the exploration of other worlds begins in earnest.

Titan is the largest satellite of Saturn. It is also, according to recent work by Joseph Veverka, James Elliot and others at Cornell University, the largest satellite in the solar system — about 3,600 miles in diameter. Titan is larger than Mercury and nearly as large as Mars. And yet, there it is in orbit around Saturn.

We might obtain some clues about the nature of Titan by examining the two major worlds in the outer solar system — Jupiter and Saturn. Both have a general reddish or brownish coloration; that is, the upper layer of clouds that we see from Earth primarily have this hue. Something in the atmosphere and clouds of these planets is strongly absorbing blue and ultraviolet (UV) light so that the light that is reflected back to us is primarily red. The outer solar system, in fact, has a number of objects which are remarkably red.

Titan, too, is an exceptionally red object. We have no color photographs of it because it is 800 million miles away and has an angular size smaller than the Galilean satellites of Jupiter. But photoelectric studies reveal that it is very red. Astronomers who thought about the problem once believed that Titan was red for the same reason that Mars is red — a rusty surface. But then Titan would be red for a different reason than Jupiter and Saturn are, because we do not see a solid surface on those planets.

In 1944, the late Gerard Kuiper spectroscopically detected an atmosphere of methane around Titan — the first satellite found to have an atmosphere. Since then, the methane observations have been confirmed — and at least moderately convincing evidence for the presence of molecular hydrogen has been provided by Lawrence Trafton of the University of Texas.

Since we know the amount of gas necessary to produce the observed spectral absorption features and we know from its mass and radius the surface gravity of Titan, we can deduce the minimum atmospheric pressure. We find it is something like 10 millibars (about one percent of Earth's atmospheric pressure) — a pressure which exceeds that of Mars. Titan has the most Earthlike atmospheric pressure in the solar system.

Not only the best, but the only visual telescopic observations of Titan have been performed by Audouin Dollfus at Meudon Observatory in France; his drawings are shown on this page. These are hand drawings made at the telescope during moments of good seeing. From the variable patches he observed, Dollfus concluded that things are happening on Titan that do not correlate with the satellite's rotation period. (Titan is thought to always face Saturn, as the moon does to Earth.) Dollfus guessed that there might be clouds — at least of a patchy sort — on Titan.

Our knowledge of Titan has made a number of substantial quantum jumps forward. In recent years astronomers have successfully obtained the polarization curve of small objects. The idea is that initially unpolarized sunlight falls on Titan, say, and is polarized on reflection. The polarization is detected by a device similar in principle but more sophisticated and sensitive than polaroid sunglasses. The amount of polarization is measured as Titan goes through a small range of phases — between "full" Titan and slightly "gibbous" Titan. The resulting polarization curve, when compared to laboratory polarization curves, gives information on the size and composition of the material responsible for the polarization.

The first polarization observations of Titan (made by Veverka) indicated that the sunlight reflected back from Titan is reflected off clouds, and not off a solid surface. Apparently there is on Titan a surface and a lower atmosphere that we do not

After a four year voyage from Earth, Mariner 11 skims only a few thousand miles above the rusty red clouds of Titan, Saturn's largest moon. During its investigation of the ringed planet in 1981, the spacecraft is expected to return hundreds of close-up photos of several Saturnian moons. Titan has an atmosphere that is more Earthlike — in terms of density — than any other world in the solar system.

Artwork by John Clark

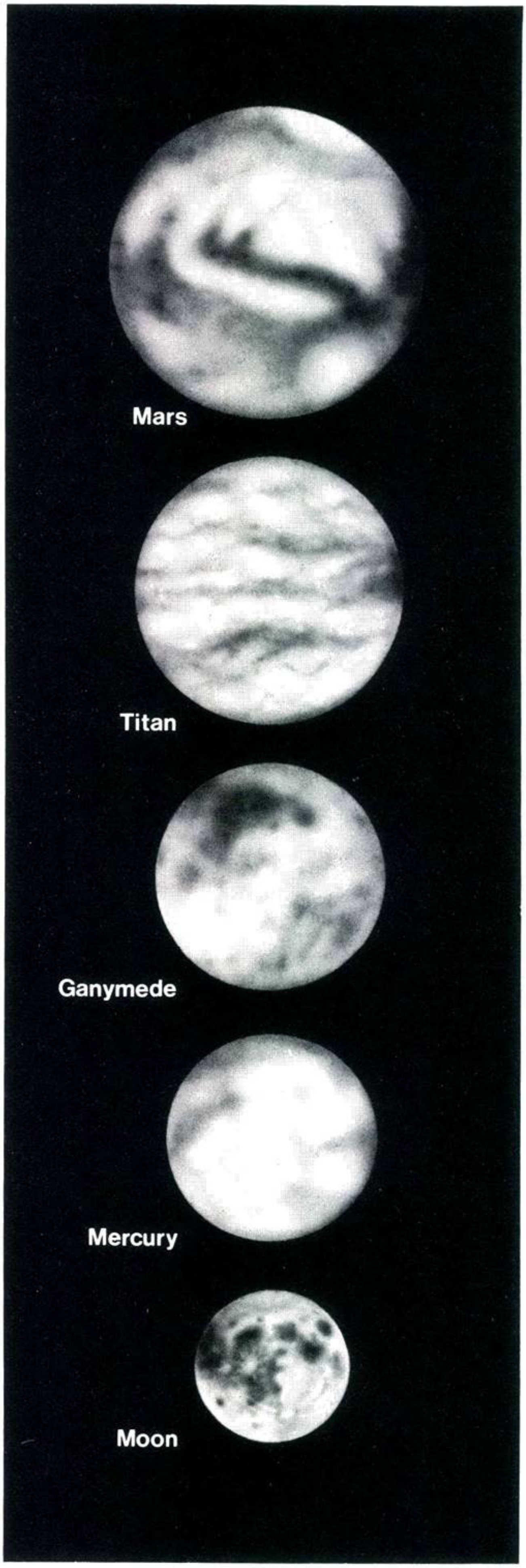
see; an opaque cloud deck superimposed by a reflective atmosphere, both of which we do see, and an occasional patchy cloud above that. Since Titan appears red, and we view it at the cloud deck, there must be red clouds on Titan.

Additional support for this concept comes from the extremely low amount of ultraviolet light reflected from Titan, as measured by the Orbiting Astronomical Observatory. The only way to keep Titan's UV brightness small is to have the UV absorbing stuff high up in the atmosphere. Otherwise, *Rayleigh scattering* by the atmospheric molecules themselves would make Titan bright in the ultraviolet. (*Rayleigh scattering* is the scattering of light by the molecules in the air which produce our blue sky.) But material which absorbs in the ultraviolet and violet appears red at visual wavelengths. So there are two separate lines of evidence (or three, if we believe the hand drawings) for an extensive cloud cover on Titan.

What do we mean by extensive? More than 90 percent of Titan must be cloaked in clouds to match the polarization data. Titan seems to be covered by dense red clouds.

A second astonishing development was inaugurated in 1971 when D.A. Allen of Cambridge University and T.L. Murdock of the University of Minnesota found that the observed infrared emission from Titan at a wavelength of 10 to 14 microns is more than twice what is expected from solar heating. Titan is too small to have a significant internal energy source like Jupiter or Saturn. The only explanation seemed to be the *greenhouse effect* in which an atmosphere is transparent to visible sunlight but opaque to infrared emission from the surface. The surface temperature then rises until the infrared radiation trickling out just balances the absorbed visible radiation coming in. It is the greenhouse effect which keeps the surface temperature of Earth above freezing and the temperature of Venus at 890 degrees Fahrenheit.

But what could cause a Titanian greenhouse effect? It is unlikely to be carbon dioxide and water vapor as on Earth and Venus, because these gases should be largely frozen out on Titan. A few hundred millibars of molecular hydrogen (1,000 millibars is the sea level atmospheric pressure on Earth) would provide an adequate greenhouse effect. Since this is more than the amount of hydrogen observed, the clouds would have to be opaque at certain short wavelengths and more nearly transparent at certain longer wavelengths. James Pollack, at NASA's Ames Research Center, calculated that a few hundred



Titan has the densest atmosphere of any object approximately its size in the solar system. Mars is larger (4,218 miles in diameter compared to Titan's 3,600) and Mercury is more massive, but Titan's location in the outer solar system has permitted a relatively dense atmosphere to evolve and be retained.

Artwork by Victor Costanzo

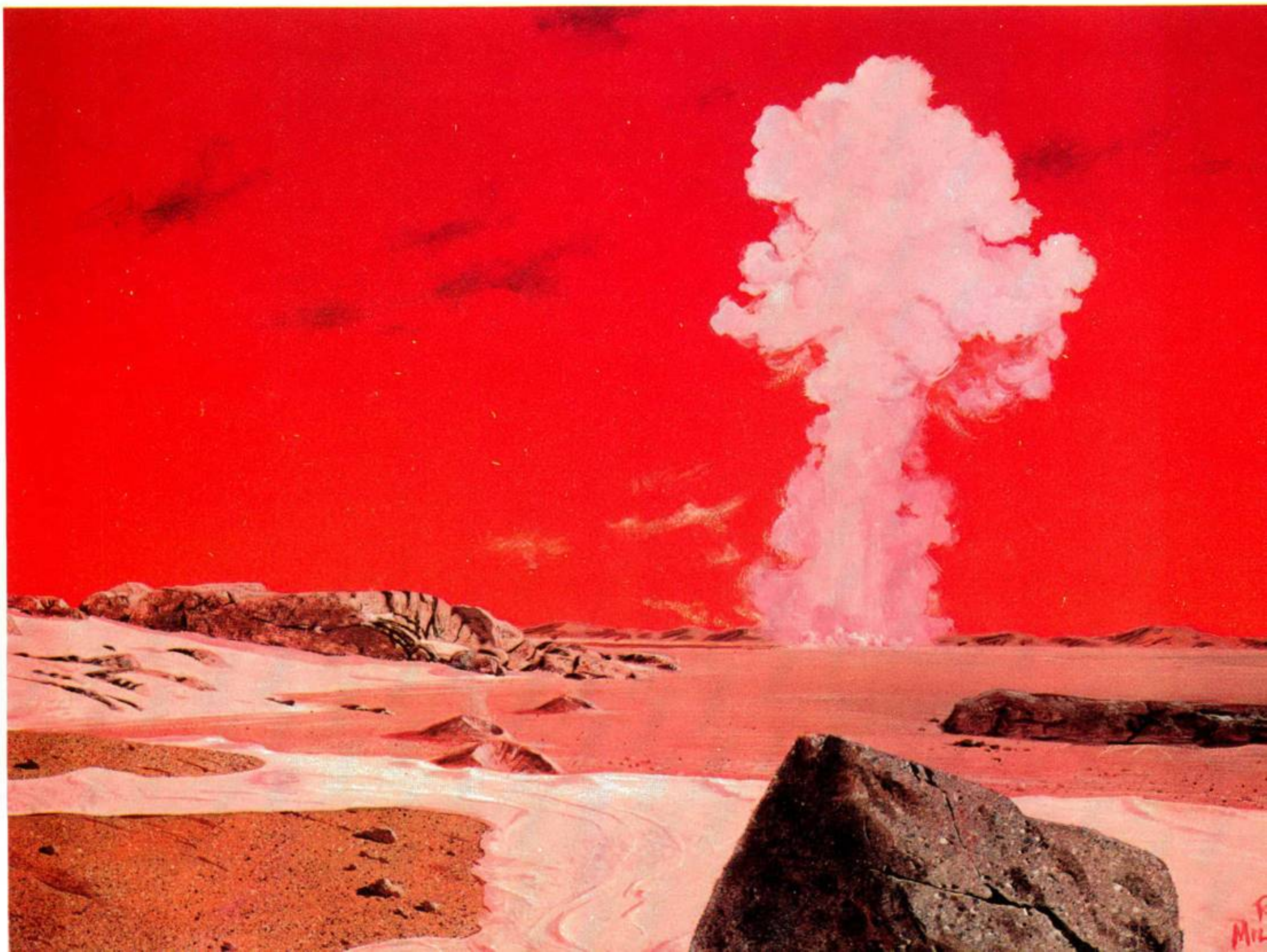
millibars of methane might also be adequate, and moreover might explain some of the details of the infrared emission spectrum of Titan. This large amount of methane would also have to hide under the clouds. Both greenhouse models have the virtue that they invoke only gases known to exist on Titan; of course both gases might play a role.

An alternative model of the Titan atmosphere was proposed by Robert Danielson and his colleagues at Princeton University. They suggest that small quantities of simple hydrocarbons — such as ethane, ethylene and acetylene — in the upper atmosphere of Titan absorb ultraviolet light from the sun and heat the upper atmosphere. It is then the hot upper atmosphere and not the surface that we see in the infrared. On this model, there need be no enigmatically warm surface, no greenhouse effect, and no atmospheric pressure of hundreds of millibars.

Which view is correct? At the present time no one knows. The situation is reminiscent of studies of Venus in the early 1960s when the planet's radio brightness temperature was known to be high; but whether the emission was from a hot surface or a hot region of the atmosphere was (appropriately!) hotly debated. Since radio waves pass through all but the densest atmospheres and clouds, the Titan problem might be resolved if we had a reliable measure of the radio brightness temperature of the satellite. The most reliable (and only) such measurement to date was performed by Frank Briggs of Cornell with the giant interferometer at the National Radio Astronomy Observatory in Green Bank, W. Va. Briggs found a surface temperature of Titan of -220 degrees Fahrenheit, with an uncertainty of 80 degrees. The temperature in the absence of a greenhouse effect is expected to be about -300 degrees Fahrenheit. Briggs' observations therefore seem to suggest a fairly sizable greenhouse effect and a dense atmosphere — but the probable error of the measurements is still so large as to permit the zero greenhouse case.

The problem could be resolved if we could measure the size of the solid surface of Titan by radar (optical measurements give us the distance from cloudtop to cloudtop). But even the upgraded Arecibo telescope will probably be unable to make this measurement. The problem may have to await studies by the Mariner Jupiter/Saturn mission, which is scheduled to send two sophisticated spacecraft by Titan — one very close to it — in 1981. (See "Missions to the Giant Planets", February 1975.)

Whichever model we select, there seems no doubt about the red clouds. But what are they? If we take an atmosphere of methane and hydrogen and supply energy to it, we will make a range of

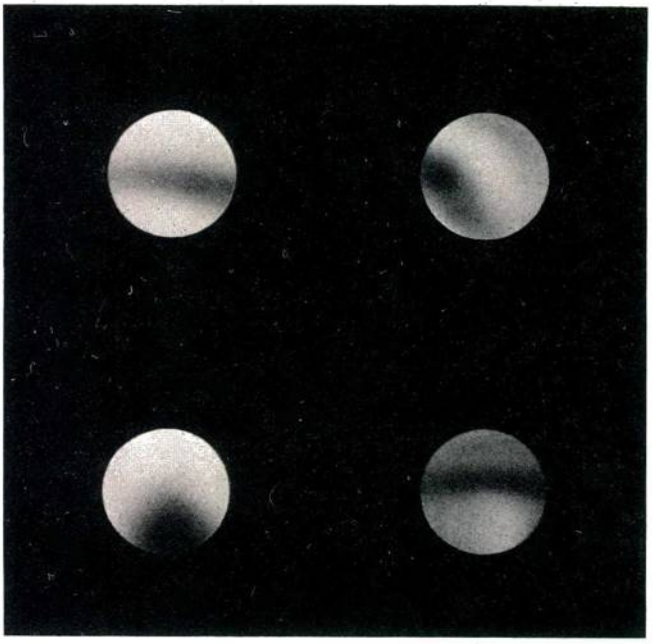


organic compounds — both simply hydrocarbons (such as the sort that are needed to make Danielson's inversion layer in the upper atmosphere) and complex ones. In our laboratory at Cornell, Bishun Khare and I have simulated the kinds of atmospheres that exist in the outer solar system. The complex organic molecules which we synthesize have optical properties similar to those of the Titanian clouds. We think there is strong evidence for abundant organic compounds on Titan — both simple gases in the atmosphere and more complex organics in the clouds and on the surface.

One problem with an extensive Titanian atmosphere is that the light gas hydrogen should be gushing away because of the low gravity. This situation can be explained by the fact that the hydrogen is in a "steady state". That is, it escapes but is replenished from some internal source — volcanos, most likely. The density of Titan is so low that its interior must be almost entirely composed of ices. We can think of it as a giant comet made of methane, ammonia and water ices. There must also be a small admixture of radioactive elements. The conduction problem has been worked out by John Lewis of MIT, and it is clear that the near-surface interior of Titan will be slushy. Methane, ammonia and water vapor should be outgassed from the interior, and broken down by ultraviolet sunlight producing atmospheric hydrogen and cloud organic compounds at the same time. There may be surface volcanos made of ice instead of rock, spewing out in occasional eruptions not liquid rock but liquid ice — a lava of running methane, ammonia and perhaps water.

There is another consequence of the escape of all this hydrogen. An atmospheric molecule which achieves escape velocity from Titan generally does not have escape velocity from Saturn. Thus, as Thomas McDonough and the late Neil Brice of Cornell have pointed out, the hydrogen which is being lost from Titan will form a diffuse toroid or doughnut of hydrogen gas around Saturn. This is a very interesting prediction — first made for Titan, but possibly relevant for other satellites as well. Pioneer 10 may have detected such a hydrogen toroid around Jupiter in the vicinity of Io. As Pioneer 11 flys near Titan it may be able to detect the Titan toroid, and Mariner Jupiter/Saturn should be able to detect it as well.

Titan will be the easiest object to explore in the outer solar system. Nearly atmosphereless worlds such as Io or the asteroids present a landing problem because we cannot use atmospheric braking. Giant worlds such as Jupiter and Saturn have the opposite problem: The acceleration due to gravity is so large and the atmosphere increases in density so rapidly that it is difficult to devise an atmospheric probe that will not burn up on entry. Titan, however, has a dense enough atmosphere and a low enough gravity. If it were a little closer, we probably would be launching entry probes there today.



Artwork by Victor Costanzo

In the 1940s, Bernard Lyot and his colleagues used the 24 inch refractor at France's Pic du Midi Observatory to detect subtle markings on Titan. Only shadings seen by more than one observer were included in the drawings. The views shown here are from a series of more than a dozen using 1,000 and 1,250 magnifications.

Titan is a lovely, baffling and instructive world which we have suddenly realized is accessible for exploration — by flybys to determine the gross global parameters; by entry probes to sample the red clouds and unknown atmosphere, and by landers to examine a surface like none we know. Titan provides a remarkable opportunity to study the kinds of organic chemistry that on Earth may have led to the origin of life. Despite the low temperatures, a Titanian biology has by no means been excluded. The geology of the surface may be unique in all the solar system. Titan is waiting....

The sky of Titan is bathed in red light transmitted through the clouds which absorb blue and ultraviolet light. An ice volcano in the distance belches methane, ammonia and water high into the atmosphere of this bizarre world. Titan is believed to have a very low density — about twice that of water and less than that of ordinary rock — suggesting a mixture of ice and rock throughout the interior.

Artwork by Ron Miller

Dr. Carl Sagan is director of the Laboratory for Planetary Studies at Cornell University and is internationally recognized as an authority on the planets and their satellites. He played a prominent role in the planning stages for several unmanned planetary probes and was largely responsible for Mariner 9's photography of the moons of Mars. In 1971 he was leader of the United States delegation to the Conference on Communication with Extraterrestrial Intelligence, organized jointly by the U.S. National Academy of Science and the Soviet Academy of Sciences. He has authored, co-authored or edited 14 books and is editor of **Icarus**, *the international journal for solar system studies. His most recent nontechnical book,* **The Cosmic Connection — An Extraterrestrial Perspective**, *was reviewed in the August 1974 issue.*

Future Exploration of the Moon

by
James E. Oberg

Predictions about the future tend to be overoptimistic in the near range and underoptimistic in the far range. The rate of technological progress in the past few decades has been unprecedented in its growth and continued acceleration, and all linear projections are bound to fall short of reality. Even the most extravagant forecasts for the next 50 years in space may appear nearsighted and unimaginative to readers of dusty microfilms in the 21st century, as any contemporary reading of predictions made in the 1920s will graphically illustrate.

In a single human lifetime, men have conquered the air and have reached out to another world. In the lifetime of today's children (and perhaps even some adults), will we see similar advances? Will we see the first voyages to the nearest stars? What new worlds and new ideas will be explored? Where will the vision of today's prophets fail?

Can we imagine space engines whose ancestors are still only engineers' dreams — engines which will take 21st century explorers from Earth to Jupiter in a week, and to the frozen comet belts beyond Pluto in a month? Such power would open up the solar system to human activity.

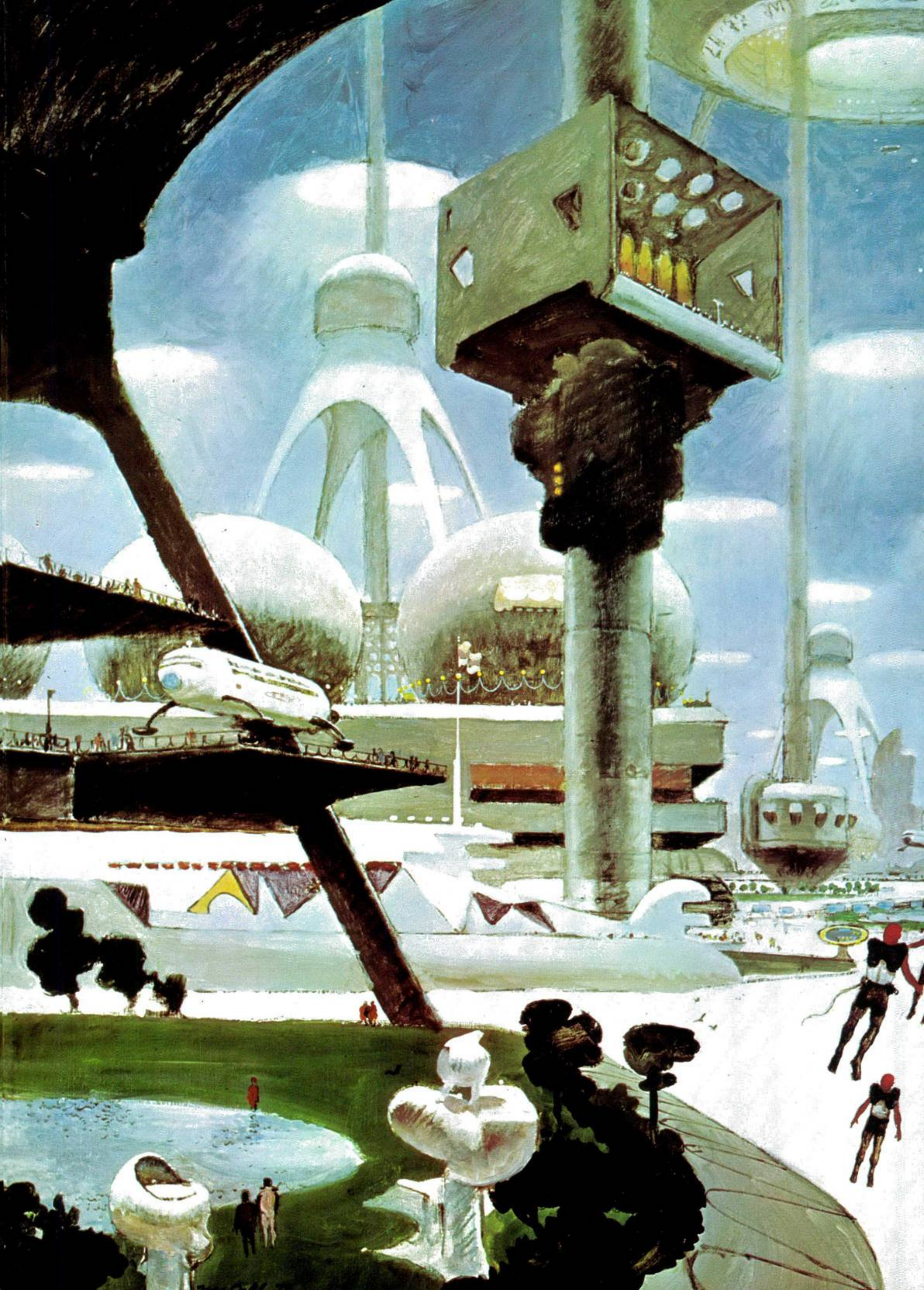
Can we imagine the manipulation of electromagnetic radiation with laws of physics discovered on space laboratories? Explorers could overcome the solar heat on Mercury and avoid the trapped particles of Jupiter's radiation belts on Ganymede.

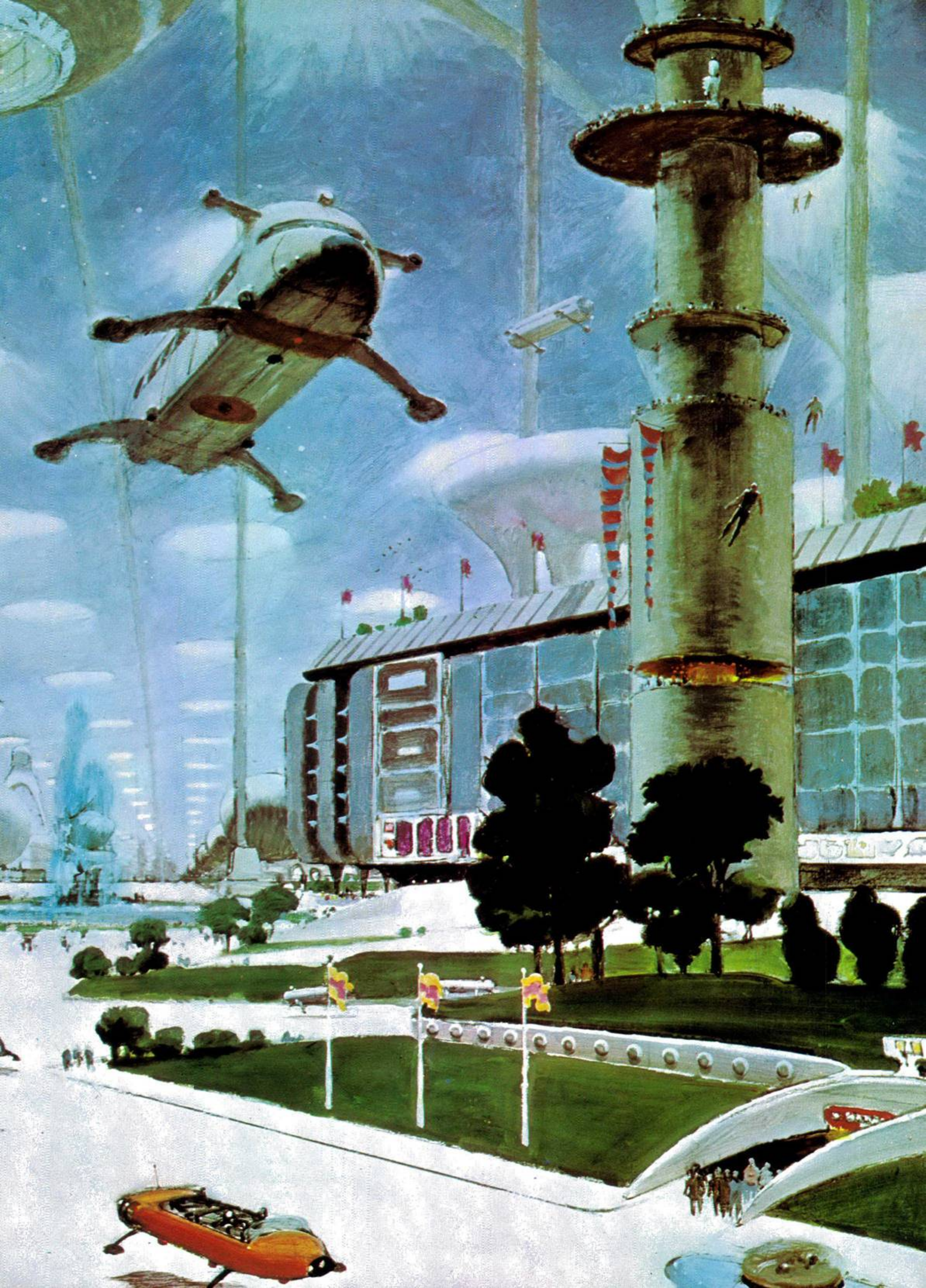
Can we imagine what the radio telescopes of the moon will detect — radio telescopes cradled in 100 mile wide lunar craters? Will we hear the birth cries of our universe or the dying whimpers of some alien civilization?

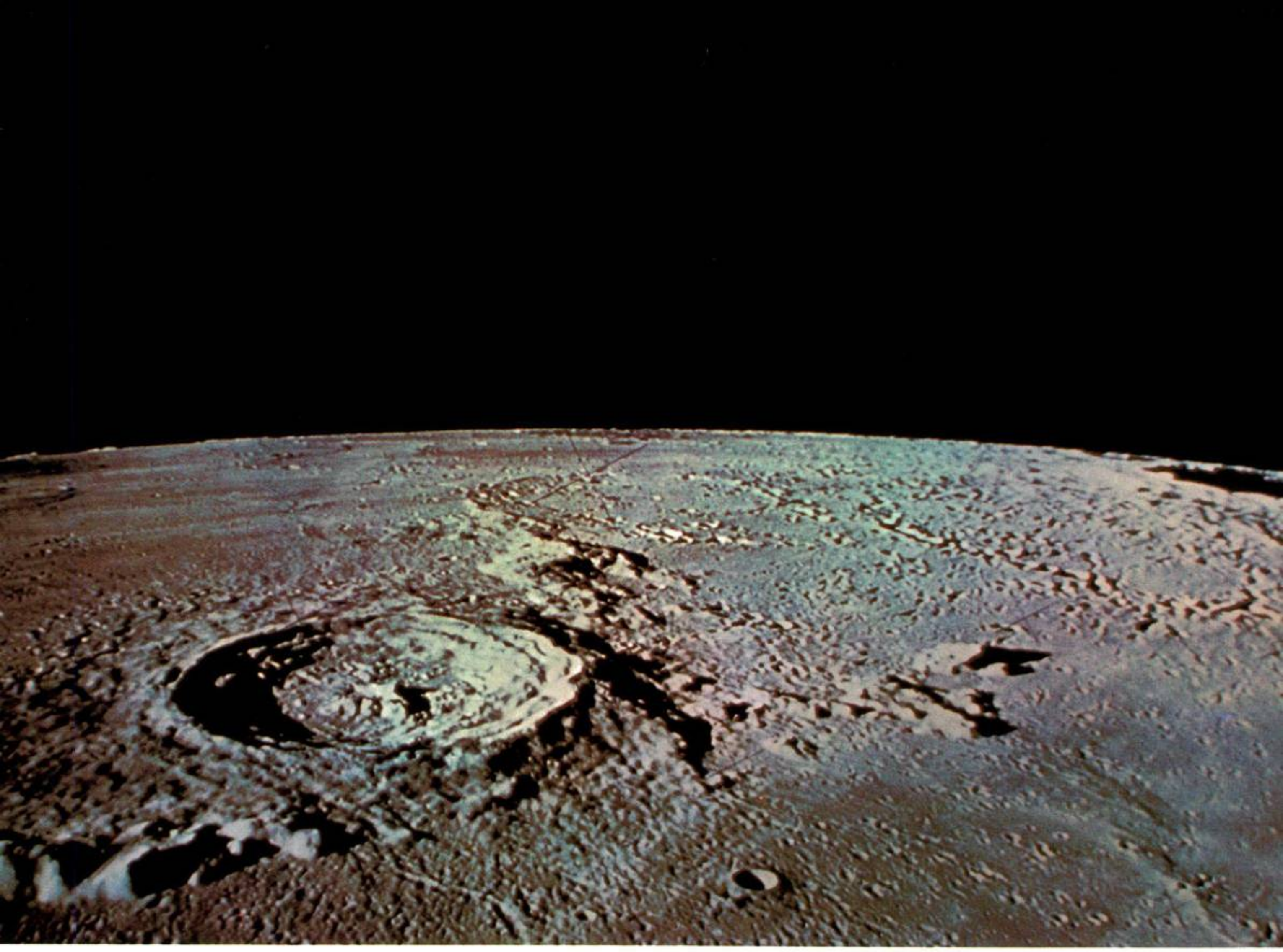
The exploration of the moon has been compared to the exploration of Antarctica. After a few spectacular and costly races to the south pole early in the 20th century, exploration was abandoned for a generation. When men returned soon after World War II, they came with new transportation devices and new technologies for living and working at the bottom of the world. Today, a year-round scientific settlement flourishes right at the south pole, and the first tourists arrived in Antarctica a few years ago.

For all the historical parallels with earlier explorations, and for all the conjured metaphors of

During their final orbit of the moon the Apollo 17 astronauts watched the crescent Earth rise over the barren craterlands of the lunar "farside". Man's return to the moon is discussed in this article. NASA Photograph







NASA Photograph

The lunar surface is stark and foreboding — but so was Antarctica at the beginning of this century. Continued exploration of the moon is inevitable; the only question is when? In the foreground of this Apollo 17 photo is the 37 mile wide crater Eratosthenes. At the extreme right on the horizon we glimpse part of the crater Copernicus.

the meanings of space exploration, the movement of men from Earth to the moon is a totally new phenomenon in human history. It cannot be judged or described with standard criteria. Catalogs of future miracles and chronicles of imaginary marvels will prove useful not if they accidentally become true but only if they inspire people to want them to become true. This, then, is how things might be in the next 50 years; this is how we want things to be.

Moon Settlement

Man's first shelter on the moon was a one room lunar module with two hammocks, a pair of windows, two doors, and no hot water. Six temporary basecamps were set up during project Apollo, and two-man teams lived in them for up to three days.

A highly developed city beneath the moon's surface is pictured here as it may appear sometime in the 21st century. The inhabitants dwell in an idyllic environment — perpetual daylight and perfect weather — and in the reduced gravity people move about with ease. Slow moving hovercraft buses provide transportation within the city's center. The tall columns provide elevator service to the surface.

Artwork by Robert McCall

Later visitors in the 1980s will construct long duration shelters. They may be made from inflatable shelters or from used rocket tanks. A few feet of lunar soil piled on top of the shelter will provide excellent thermal insulation and protection from meteorites.

Moon explorers will live in these temporary buildings while mining the moon for water-bearing rocks. Some of this activity will be surface strip mining, but there will also be underground digging. These excavations will be done with nuclear explosives or with rock-eating "subterrenes" (nuclear-powered drills which can melt their way through solid granite). These tunnels can then be pressurized, lit, and heated to provide additional living, working, and storage space. Entire strata under the lava flows can be cleared, with the lava forming a solid self-supporting ceiling.

Men will go back to the moon and to this kind of life for the same reasons which took them there in the first place. It will be an effort to capture the imagination of the world, to challenge and improve current engineering techniques, to learn about important problems facing mankind, and to advance scientific knowledge. Returning to the moon can also be profitable.

A second Apollo type project in the mid-1980s (will it be called "Artemis" or "Diana" or "Selena"?) can be dedicated to the establishment of a self-sufficient lunar colony. The problems involved will be concerned with shelter engineering, ecology and biological recycling, and human interaction. With the large but still finite environment of "spaceship Earth" limping along due to man made pollution and exploitation, men need to know how to manage a closed cycle biosphere. The moon is a good place to try it out on a small scale.

The moon colony, at the end of a distant and still costly lifeline from Earth, will have to depend on locally produced resources almost from the very beginning. The first need is water and oxygen; the second is power.

The water might come from buried layers of ice permafrost, perhaps in the eternally dark craters of the north and south poles. If this is not found, it could come from hydrous volcanic rocks or from the brute force breakdown of mineral oxides. The electrical power could come from solar power or from nuclear fusion reactions. Sunlight has twice the intensity on the airless moon as it does on Earth; nuclear fusion plants might first be constructed on the moon if they prove too hazardous for use on Earth.

Other moon resources are less obvious but potentially just as valuable. Basalt is more than a common rock; it can be processed into building materials, cast into pipes and furniture, and spun-woven into insulation and cloth. The moon also has two qualities nearly unique in the inner solar system — a high quality vacuum and periods of nearly absolute zero temperatures.

The vacuum on the moon is a thousand times better than the vacuum in Earth orbit, and a million times purer than artificial vacuum chambers available on Earth. On the back side of the moon, meanwhile, specially insulated materials can, after two weeks of darkness, cool off nearly to the point where all molecular motion stops. Strange phenomena occur near this absolute zero.

Although there is not likely to be any raw material on the moon which is worth the transport fee back to Earth, the moon's own environment will be valuable for the kinds of processing which can be done there. Many types of high technology products are fabulously costly on Earth only because of the needs to create special conditions which occur

NASA Photograph

The exploration of the moon during the Apollo program has been compared to the daring conquest of the Arctic and Antarctic regions of Earth early in this century. It seems inevitable that man will return to the moon to establish permanent research bases in preparation for eventual odysseys to more distant worlds.

free on the moon. Such products will be well worth the cost of transport back from the moon.

The colony on the moon will be technologically feasible, and potentially rewarding in economy, science, and engineering long before it becomes politically feasible. The capabilities to build it are not enough; the will to build it must come first.

Moon Transportation

Mobility on the moon will be one of the factors limiting human activity there. The Apollo astronauts walked a few miles and later drove moon jeeps a few dozen miles. New moon explorers will

need vehicles capable of taking them hundreds of miles across the lunar surface.

Wheeled moon jeeps are well suited to the rolling, sandy terrain — but they are limited to slow (10-20 m.p.h.) speeds and can be blocked by natural features like ravines or cliffs. The sizes of wheeled vehicles will range from giant tractors with pressurized living quarters to light, one-man, wide-tracked bicycles.

Without an atmosphere, the moon cannot sustain winged flight. Flying vehicles must generate their own lift with rocket thrust. The first such

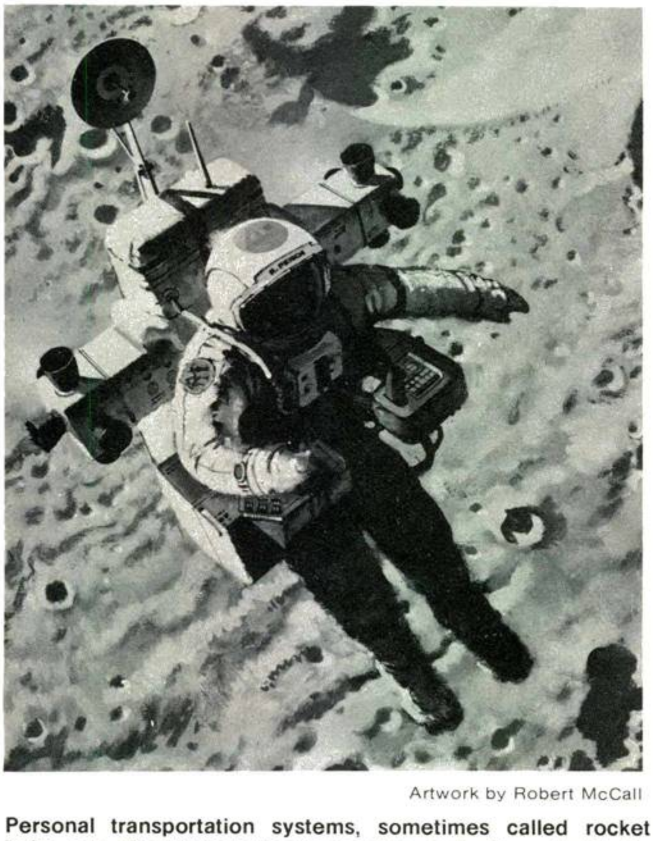
"rocket belts" were developed on Earth in the early 1960s. The moon's low gravity, combined with new fuels and rocket engineering of the 1980s, will lead to one-man flying belts, flying cargo platforms, and multiman flying laboratories the size of house trailers. Personal transportation systems will take much of the danger out of lunar exploration. With their tanks topped off with fuel from a disabled lunar module or from an emergency fuel cache, a rocket belt can carry a stranded astronaut from the lunar surface into lunar orbit, where transport ships can pick him up.

Moving around on the moon will also require more flexible space suits. The heavy Apollo suits and backpacks were bulky and restrictive, and men were exhausted after working six hours in them. Rocks had to be picked up with long tongs, and heavy gloved hands were incapable of any but the simplest repair work or instrument manipulation.

The new space suit has already been in development since before the Apollo landings. NASA called it the Space Activity Suit (SAS, or "skin" suit) — a thin overgarment which re-enforces the natural flexibility, airtightness and thermal control of human skin. A helmet and an oxygen regulator would keep the man alive while he moved freely and dexterously on the moon.

Moon railroads of the 21st century may provide heavy-duty, long haul transportation between settlements. Superconductive metal strips, cooled to near absolute zero during the lunar night, could allow electromagnetic levitation of vehicles traveling hundreds of miles per hour.

By foot, by rocket belt, rocket bus, bicycle or levitating railroad, the problem of moon transportation will be overcome. Someday it will be easier to get around on the moon than it is on Earth.



Artwork by Robert McCall

Personal transportation systems, sometimes called rocket belts, are already technically feasible and will undoubtedly be used by the next generation of lunar explorers. These devices will be capable of lofting an astronaut into lunar orbit.

Moon City

What kind of people will live on the moon? How will they live, work and play? What will they think of the moon, and of Earth?

Activities on the moon will center around engineering, metallurgy and chemistry, physics, biology, and sciences yet unknown. All the activities found in any human city — along with those needed on a frontier of science — will be found. With the underground settlements populated with scientists, artists, businessmen, lawyers and everybody else, there will really be a "man in the moon".

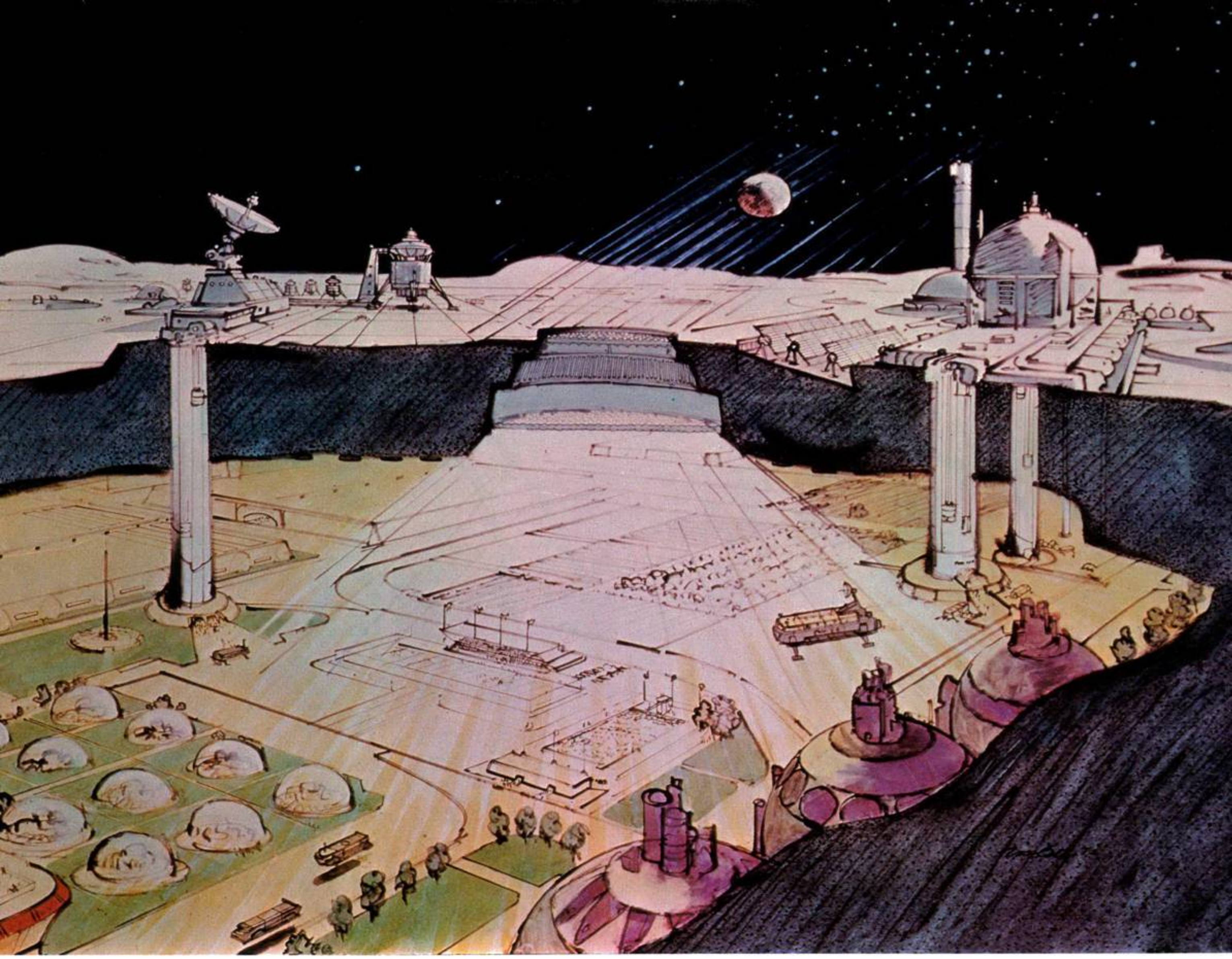
People will find new ways to play on the moon. New sports and old dreams will become possible. The low gravity and the open air of the sublunar chambers will make man-powered flight possible. With a pair of fabric wings, a man will be able to rise into the air and fly like a bird. Many dreams will come true on the airless moon, but human flight (as opposed to human riding in flying devices) is a strange and unexpected twist.

Swimming can be a popular sport and a convenient exercise. New water sports are possible. Water polo has always been a rough game on Earth; how much rougher will it be when players can hurl themselves clear of the water to grab for the ball? Swim-hurdle races will call for the contestants to throw themselves across racing barriers in their lanes, jumping clear of the water like dolphins or flying fish.

How will men on the moon divide up their days? They will be freed from the terrestrial 24 hour circadian rhythm, and they may be free to adjust the pattern of waking and sleeping. Is 8 hours asleep and 16 awake the most efficient, or even the most normal? Can a man sleep 10 hours and stay awake for 20 afterward? The cycle may be chosen to be some even fraction of the 29 day lunar "day".

The moon will still be a closed ecosystem, recycling its water, air and by-products. On Earth, green plants and ocean microorganisms are part of this cycle, and they will be needed for the same function on the moon. The lawns, wooded acres, and fresh and salt water ponds (perhaps with mechanically generated surf in the low lunar gravity) will be for more than just the esthetic pleasure of the inhabitants. They will be a direct part of the life support system.

Despite the number of men and women on the moon in 30 or 50 years, human beings will still be only visitors to another world up until the occurrence of one epochal event which will truly make the moon



Artwork by Robert McCall

A city beneath the lunar crust is a logical extension of man's exploration of our satellite's surface. Here, a vast area excavated by atomic power is supplied with an atmosphere that allows people to live much as they would on the surface of Earth. At top center is a circular solar well reaching up to the surface of the moon through which solar energy and sunlight are transmitted to the city below. The atomic power plant at upper right supplies the energy that is required by the city during the two-week lunar night. At left is a transportation facility; passengers will board the Earth ferry, and once in Earth orbit they will transfer to an Earth shuttle that will take them to the surface. (All the McCall artwork in this article is from *Our World in Space* published by the New York Graphic Society. For a review see the July 1974 issue.)

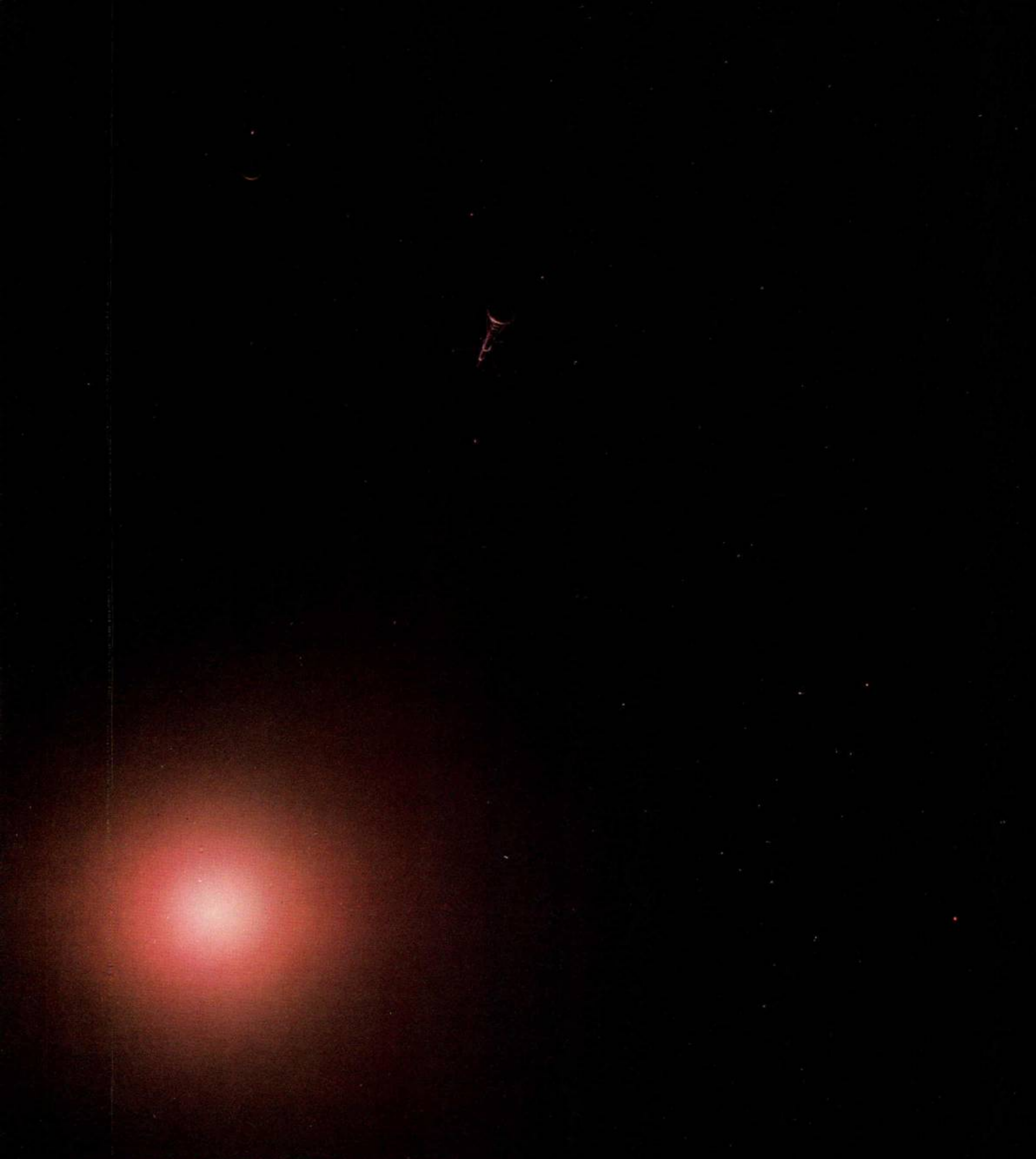
into man's second planet. This dividing moment will occur with the birth of the first baby on the moon. For the first time since life formed in the ancient oceans, Earth will no longer be "Mother Earth" to all of her children.

The moon will also cradle the children of Earth in death. Men and women will die on the moon and be buried there. Will the harsh realities of biological needs demand that their body's water and chemicals be recycled, or will men accept the cost (as they usually have) of respecting the physical form? Will there be cemeteries on the moon, or will the ashes of the dead be spread in a memorial park?

The harsh nature of the moon may be a distant reality to those who live there — even on a world where the failure of artificial life-support equipment means a quick death. But men already live in such fragile environments in Los Angeles, New York, London, and other great cities on Earth. People can take a lot for granted — on Earth and on the moon.

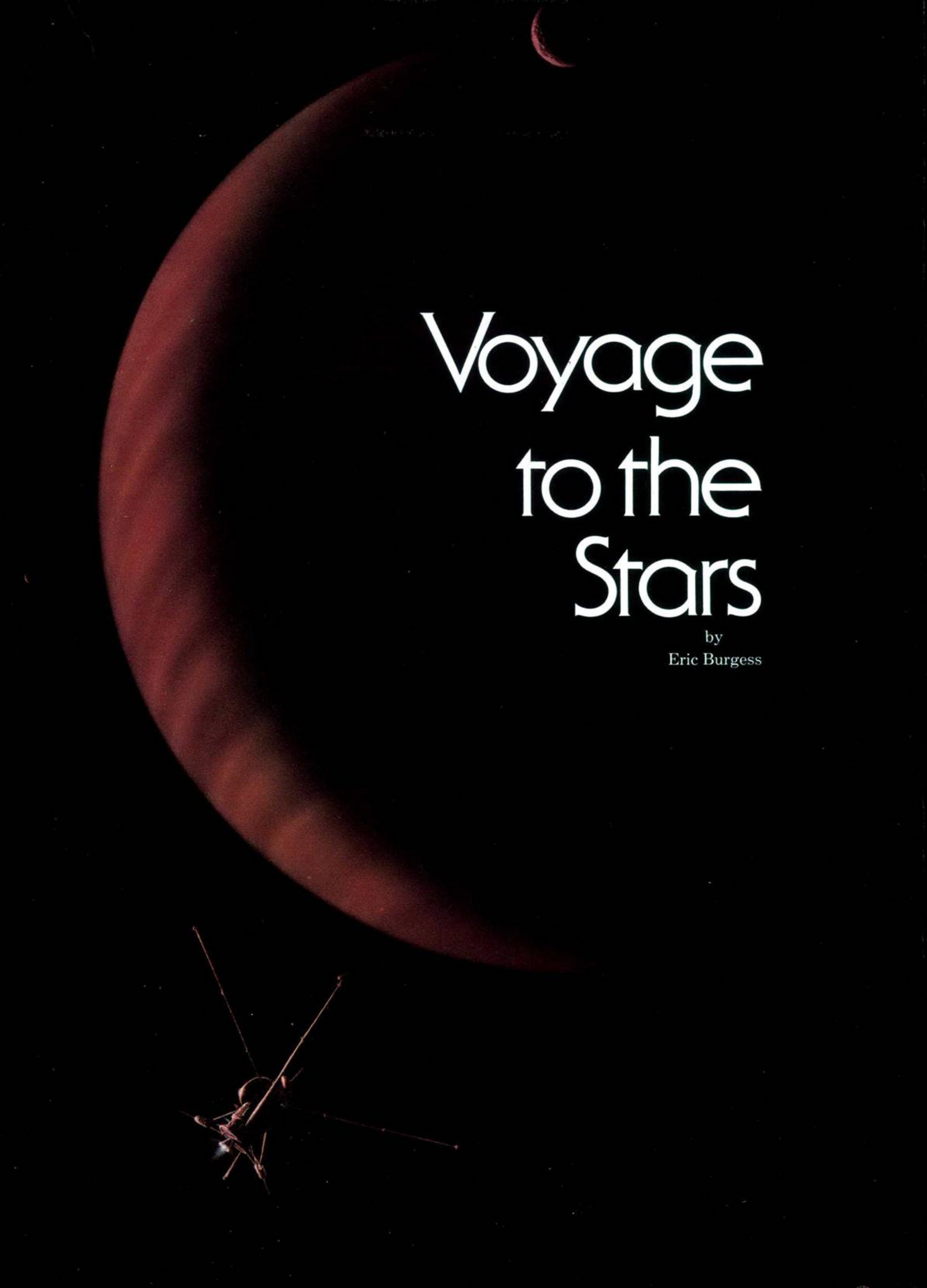
The cities of the moon will be the first subtle hints of the future of mankind. Similar subsurface cities can be built on other airless worlds. It may take centuries or a thousand years but someday the human population off Earth may become more numerous than the population still living on man's first planet. A new history can then begin. All that came before may be remembered (if at all) by a brief footnote.

James E. Oberg is a captain in the United States Air Force and currently "teaches government and military executives how to live with computers" at the DOD Computer Institute in Washington, D.C. A science writer specializing in space, Oberg is also a consultant on the Soviet Space program for the U.S. Astronaut Office in Houston. He has been a contributing editor to ASTRONOMY since early 1974.



After crossing the interstellar abyss for more than half a century, a future unmanned space probe hurtles through the planetary family of Barnard's star. As our second nearest neighbor sun, Barnard's star is the closest star that seems likely to have planets. There is considerable evidence suggesting that two Jupiter sized planets do in fact exist in this system. Barnard's star itself is a red dwarf much fainter than our sun. The spacecraft in the foreground is a small probe dispatched by the main ship (upper center). Such probes are speeding toward each planet of this system and radioing their findings back to the main craft which in turn relays the data back to Earth, six light-years away. Preliminary design studies of interstellar missions such as this are now being conducted as described in this article.

Artwork by Adolf Schaller



Voyage to the Stars

by
Eric Burgess

Today astronomy and space enthusiasts increasingly speculate about the possibilities of missions to the stars just as they once speculated about flights to the moon and planets. It is symptomatic of humanity's mental limitations that these current speculations receive the same negative comments that were leveled against the interplanetary societies of the 1930s, when the so-called incurable optimists laid the foundations for the space age.

Now that men have stepped on the lunar regolith, sent instrumented probes to obtain unprecedented close-up views of neighboring planets, and taken the first steps in exploring the outer planets with the successful Pioneer 10 and 11 slingshots around Jupiter, we are compelled to ask the question: Can man travel to the stars?

The solar system's extent of some 40 times the Earth-sun distance is insignificant compared with distances to the stars. Light, which travels to the boundary of our solar system in 5-1/2 hours, requires over four years to reach even the nearest star. Since today's physics firmly places the speed of light (186,000 miles per second) as the universe's ultimate speed limit, interplanetary flight and interstellar flight are two entirely different regimes from the standpoint of time.

Today chemically propelled spacecraft can attain velocities capable of sending them to the stars. The speed of 35,000 m.p.h. needed to escape the solar system is only 10,000 m.p.h. more than Earth's escape velocity. But such a voyage would take a long time. Even traveling at 35,000 m.p.h. mankind's first starship, Pioneer 10, will not reach the distance of the nearest star until 80,000 A.D.

To be effective, unmanned interstellar probes must move faster than Pioneer 10. The table below gives an idea of the high speeds needed to send a probe to the nearest star, Alpha Centauri, within a reasonable length of time. Even at 10 percent the speed of light, the craft would be traveling over 2,500 times faster than Pioneer, and would correspondingly need propulsion systems vastly more powerful than anything we have now.

One-tenth light's velocity is about the minimum speed we would ever want an unmanned probe to fly — if information is to be returned in time to interest at least the nation, if not the generation, who launched (and paid for) the voyage. Scientists, much less politicians, are not likely to send out a probe knowing that only their remote descendants will get a message back. The sluggish probe might eventually find itself being passed up by a much faster craft developed a generation or two later!

The Project Daedalus study recently completed by the British Interplanetary Society envisions a 151,000 ton unmanned probe driven toward Barnard's star at 17 percent light's velocity by a continuous string of tiny nuclear explosions — somewhat like lighting a string of firecrackers behind a tin can. Miniature fuel pellets of a deuterium (a hydrogen isotope twice the weight of normal hydrogen) and helium 3 (a form of helium) mixture would fire into the center of a magnetic field at 250 pellets per second. Four electron beams then compress and heat each pellet until it explodes by nuclear fusion. A cup shaped molybdenum shell absorbs the energy of the expanding ball of plasma and pushes the craft forward. Fuel would account for 99 percent of the ship's weight.

To save propellant, the star probe could be placed on a flyby trajectory rather than decelerating into orbit around the target star. A sophisticated machine intelligence (reminiscent of the "2001" HAL 9000) would launch some 10 to 20 small probes from the mother ship to fly through the alien solar system on different trajectories to search for and investigate the planets.

Unmanned interstellar probes coasting at a fraction of the speed of light may journey to stars within a 12 light-year (one light-year equals 5.9

UNMANNED MISSION TIMETABLE FOR FLYBY OF ALPHA CENTAURI SYSTEM

Maximum Velocity (% of speed of light)	Acceleration Time at 1G*	Coast Time (years)	Data Return (years)	Total Mission Time (years)
100	—	4.3	4.3	8.6
50	5	6	4.3	15
40	4	9	4.3	17
30	3	13	4.3	20
20	2	21	4.3	27
10	1	43	4.3	47
5	.5	85	4.3	90

*1G equals the acceleration of gravity at sea level on Earth.

(Based on calculations by Robert L. Forward, senior staff physicist, Hughes Research Laboratories.)

STARS WITHIN 12 LIGHT-YEARS

Name	Distance (light-years)	Mass (sun=1)	Luminosity (sun=1)	Spectral Class	Comments
Sun	—	1.0	1.0	G2	
Alpha Centauri A	4.3	1.1	1.3	G2	Nearest star system. A and B components separated by an average distance of 23 A.U.*; component C is 10,000 A.U. from center of system.
Alpha Centauri B	—	0.7	0.36	K5	
Alpha Centauri C	—	0.2	0.00006	M5	
Barnard's star	5.9	0.2	0.00044	M5	Two unseen planets about Jupiter's mass are suspected to orbit this star.
Wolf 359	7.6	0.2	0.00002	M6	
Lalande 21185	8.1	0.3	0.0052	M2	Unseen companion 10 times Jupiter's mass has orbital period of 8 years.
Sirius A	8.6	2.4	23	A1	
Sirius B	—	1.0	0.008	white dwarf	
Luyten 726-8-A	8.9	0.2	0.00006	M6	These are the least massive stars known, each averaging about 40 times Jupiter's mass.
Luyten 726-8 B	—	0.2	0.00004	M6	
Ross 154	9.4	0.2	0.0004	M5	
Ross 248	10.3	0.2	0.0001	M6	
Epsilon Eridani	10.7	0.6	0.3	K2	Unseen companion 6 times Jupiter's mass believed to have 25 year orbit.
Luyten 789-6	10.8	0.2	0.00012	M6	
Ross 128	10.8	0.2	0.00033	M5	
61 Cygni A	11.2	0.7	0.083	K5	Unseen companion 8 times Jupiter's mass follows 4.8 year orbit.
61 Cygni B	—	0.8	0.040	K7	
Epsilon Indi	11.2	0.7	0.13	K5	
Procyon A	11.4	1.7x	7.6	F5	
Procyon B	—	0.7	0.0005	white dwarf	
Sigma 2398 A	11.5	0.3	0.0028	M3.5	
Sigma 2398 B	—	0.3	0.0013	M4	
Groombridge 34 A	11.6	0.4	0.0058	M1	
Groombridge 34 B	—	0.2	0.0004	M6	
Lacaille 9352	11.7	0.3	0.012	M2	
Tau Ceti	11.9	0.9	0.44	G8	Nearest single star similar to the sun.

***One A.U. (Astronomical Unit) equals the average distance from Earth to the sun — 92,960,000 miles. Interstellar probes to these stars will not be sent with the purpose of detecting life. Only Tau Ceti seems even remotely likely to have planets similar to Earth. The exploration of these stars and their planets will be a prelude to missions to specific targets beyond our immediate stellar neighborhood. For a list of stars with the highest potential of having Earthlike planets, see page 17 in the December 1974 issue.**

trillion miles) radius before the end of the next century. But what are man's chances of following his robot trailblazers across the interstellar abyss? Certainly this ranks as one of the most beckoning challenges that mankind may ever face. To actually visit neighboring solar systems and make direct contact with alien life or civilizations, and to attempt colonizing extrasolar planets, spreading man's heritage across the galaxy, is irresistible.

Although the cost and complexity of such an undertaking seems incredible, physics does not impose any insurmountable barriers. We are only limited by our skill and imagination. Here's a review of several popular starship schemes:

* A "space-ark" weighing hundreds of thousands of tons travels slowly as an artificial planet. Inhabitants live fairly normal lives on the vessel as generations pass by. Finally, distant descendants reach the target planet and disembark to colonize.

* A relatively small starship coasts as slowly as the space-ark but with the crew in a reduced metabolic state — either chemically or biologically modi-

fied by genetic engineering. The original humans then awake to explore or colonize.

* Advanced biological engineering prevents aging, allowing willing volunteers to spend centuries of their immortal lives aboard a slow speed vessel.

* An advanced technology starship travels at "relativistic" speeds — a sizable fraction of the speed of light. Astronauts arrive at a distant star system after perhaps less than 10 years of traveling across interstellar space.

The last of these alternatives sounds the most appealing. One need not be a superman or hibernate as a deep-space popsicle to explore other solar systems. Also, return to Earth within a relatively short length of time remains possible (at least for odysseys to nearby stars).

At speeds approaching the velocity of light, time on board a starship would appear to slow down to an outside observer, according to Einstein's *Theory of Special Relativity*. Simply, this so-called time dilation effect means that time is a flexible quantity in the universe; the rate at which it appears to flow depends upon one's speed.

Experiments in giant particle accelerators have already demonstrated this bizarre theory. Short-lived subatomic particles take a longer time to decay when they are sped up to relativistic velocities. Recently two atomic clocks were carried around the world in jet planes. The clock that flew west to east (with Earth's rotation) traveled slightly faster and measured an infinitesimal slowdown in time relative to the westbound clock.

After whizzing around Earth at 17,500 m.p.h. an astronaut returns 450 millionths of a second younger than if he had never left. But at lightlike speeds the time difference becomes dramatic. The table on page 28 shows that time dilation offers man a powerful, almost magical chance to vault tremendous distances within average human lifetimes. Even nearby galaxies fall within our grasp.

To demonstrate time dilation, we'll simultaneously board a hyperspeed starship of the distant future and also watch its progress from Earth. As mighty engines blast the vessel out of Earth orbit its on board clock and an Earth based clock read identical hours, minutes and seconds. Ponderously, the colossus begins accelerating at 32 feet per second^2 (equal to the acceleration of gravity on Earth's surface — 1G), soon breaking one million m.p.h. before the end of its first day after launch.

Ten months later the starship's still constant 1G acceleration carries it past the 580 million m.p.h. mark (87 percent light's velocity). Now for every two seconds on the Earth clock the ship's chronometer reads one second — the two clocks rapidly drift out of synchronization. Forty days later as velocity climbs to 656 million m.p.h. (98 percent light's velocity), each crew member's heart beats once for every five human heartbeats on Earth. At 99.5 percent the velocity of light, less than a day passes by on the ship for every week on Earth. And at 99.99 percent, one year flashes by on Earth for every 3-1/2 ship days. In the next six months that the crew spends within the ship, all relatives and friends left behind will have completed their Earthly lives.

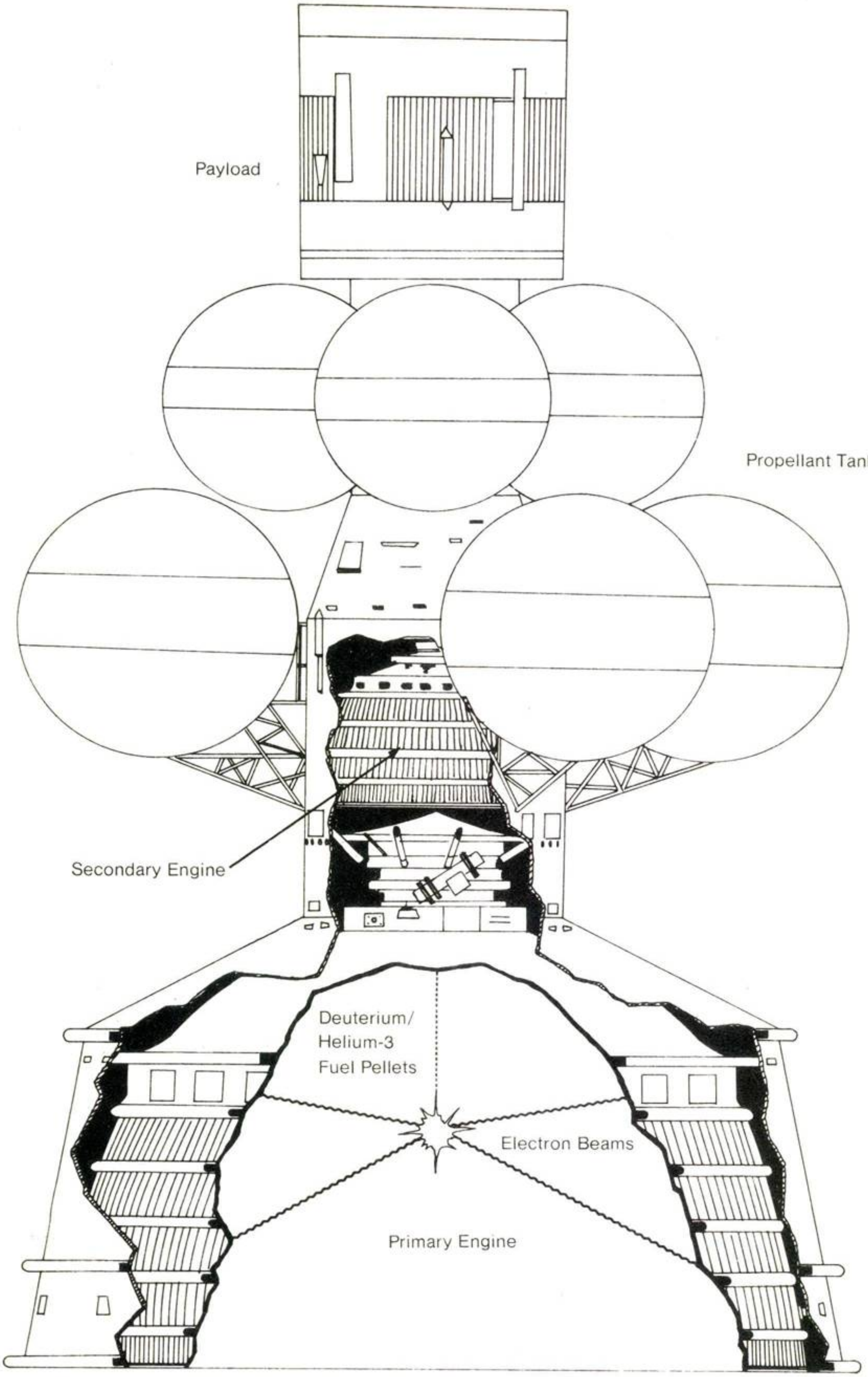
After accelerating for one year the ship's engines shut down, and it coasts toward the globular star cluster M-13, 25,000 light-years distant. To observers on Earth the astronauts would appear frozen like figures in a wax museum, but on board the vessel time seems, and *is*, normal — their clock continues faithfully logging minutes and seconds. Theoretically, if the crew could train some supertelescope back on Earth, all activity on our planet would appear speeded up to a blindingly fast pace. The crew would feel like time travelers straight out of the H.G. Wells novel, except that theirs is a one-way trip. As 500 centuries melt by on Earth only four or five decades elapse within the ship's hull as the voyagers complete their round trip. The returning star trekkers could easily find themselves on an Earth as culturally alien as the civilizations they encountered in M-13.

But the energy requirements for hurling even a modest sized manned spacecraft into relativistic velocities staggers comprehension — at least by today's standards. Some engineers calculate that the required energy expenditure would supply all United States electrical power for over 100,000 years (at the level of current usage).

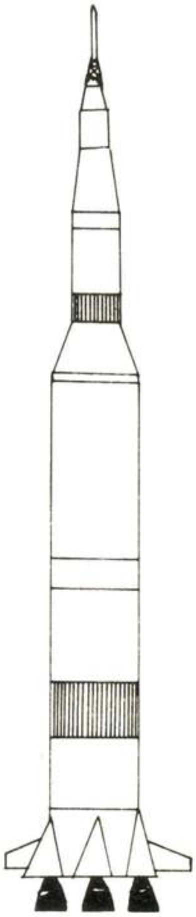
The most formidable problem involves keeping propellant weight down to reasonable levels. This demands finding a fuel far more energetic than anything we have now, and developing a rocket engine that works at almost 100 percent efficiency. The engine must flawlessly fire continuously for long periods of time (at least one year at 1G acceleration) and carry enough propellant for the round trip.

At first analysis it might seem that with current technology, interstellar travel — even by unmanned probes — is beyond the realm of engineering. However let's not too quickly declare interstellar travel impossible, considering that in the 1930s engineers were insisting that rockets the size of mountains would be needed to reach the moon. Professor F.R. Moulton of the University of Chicago wrote, "There is not in sight any source of energy that would be a fair start toward that which would be necessary to get us beyond the gravitate control of Earth."

As late as the 1950s, many reputable engineers and scientists "proved" that ballistic missiles were unlikely to attain intercontinental velocities, that Earth satellites were impractical if not impossible, and that probes to other planets and manned flights to the moon were fantasy. In 1953, a major survey of expected developments in aeronautics over the next 50 years by a top panel of aviation and missile "experts" completely ignored spacecraft and only cautiously hoped for supersonic operational flight!


Payload
Propellant Tanks
Secondary Engine
Deuterium/
Helium-3
Fuel Pellets
Electron Beams
Primary Engine

Project Daedalus Starship
151,000 Tons



Saturn 5 Moon Rocket
3,750 Tons

The Project Daedalus unmanned star probe, currently under study by the British Interplanetary Society, dramatizes the scale and complexity of interstellar flight. Five hundred times more powerful than the Saturn 5 rocket, Daedalus is propelled by a string of miniature nuclear explosions. Fuel pellets streaming into the 400 foot diameter main engine individually detonate when zapped into thermonuclear temperatures by electron beams. After burning for an incredibly long five years, the main engine ejects — leaving behind a smaller motor for midcourse corrections. After hurling across space at 10 percent the speed of light for several decades, Daedalus would likely streak through its target solar system in less than 10 hours.

Artwork by John W Clark

They even failed to predict the role of ballistic missiles. If the space age was completely missed only four years before Sputnik I was launched, it seems foolish to dismiss all thoughts of interstellar flight as unrealizable dreams.

The most powerful and efficient system engineers can imagine is the matter/antimatter drive (the kind of thing that propels Captain Kirk and his gang around the galaxy). Antimatter would have the opposite electrical charge of matter — antimatter electrons being positive instead of negative, and protons negative. Mixing equal amounts of matter and antimatter results in a powerful and complete release of energy as atoms of each material electrically cancel each other out.

Ideal as antimatter sounds, physicists have only seen tiny traces of it resulting from experiments in particle accelerators — and they doubt if it naturally exists in space. Even if antimatter were discovered somewhere, safely collecting, storing and controlling large quantities of it would be an engineering nightmare.

Second only to matter/antimatter annihilation is *nuclear fusion*, the energy process that powers the stars. A single solar outburst in August 1970 threw away into space enough energy to launch 1,000 interstellar voyages.

Third in line and less exotic and challenging than fusion is *nuclear fission*. Instead of combining lighter elements to form heavier ones, fission relies upon energy released through atomically breaking down very heavy elements. All currently operating nuclear power plants rely on fission processes. The only practical work so far has been on a fission rocket engine by the successful NERVA program (which was axed several years ago in a retreat from space by the U.S. government).

Some studies suggest that nuclear-pulse rockets on a much larger scale than the craft outlined for Project Daedalus might launch man starward. In this case, 150,000 tons of nuclear bombs would sequentially explode behind the starship — a "plowshare" use of today's overkill stockpile of nuclear weapons. This pulsed starship could theoretically travel 10 light-years in 150 years. (An illustration of this type of craft appeared on page 4 of the December 1974 issue.)

Another starship concept uses helium 3 fusion. Carrying 1,000 tons of payload and weighing 100,000 tons initially it would take about 100 years to journey 10 light-years. Helium 3 is not plentiful in nature and would have to be synthesized in fusion reactors. Tritium (a hydrogen isotope three times as heavy as normal hydrogen) can also be used for starship drives except that it radioactively decays faster than helium 3. A fusion-propelled starship might burn helium 3, or tritium, mixed with deuterium to produce effective exhaust velocities (speed of propellant ejected from the spacecraft) up to 2,500 times that of today's high performance chemical engines.

Production of these synthetic nuclear fuels might be a by-product of fusion power plants developed for future global energy systems. Earth's total power consumption today amounts to about 10 billion megawatts. This is unlikely to be increased more than 10,000 times without producing heat hazards to Earth's climate. However, if humans extend into the solar system and establish colonies and manufacturing operations on other worlds such as the moon, 10 million times as much energy might be consumed as today — producing throughout the solar system the millions of tons of tritium or helium 3 to drive starships perhaps on a major interstellar colonization program.

Among the most advanced theoretical interstellar propulsion devices known today as technically feasible is a photon rocket. This device would convert matter into radiant energy and direct an intense beam of light similar to a rocket jet. With such a propulsion system, a trip to a nearby star might take only 10 years. The starship would carry 30,000 tons of fuel and push a 1,000 ton payload.

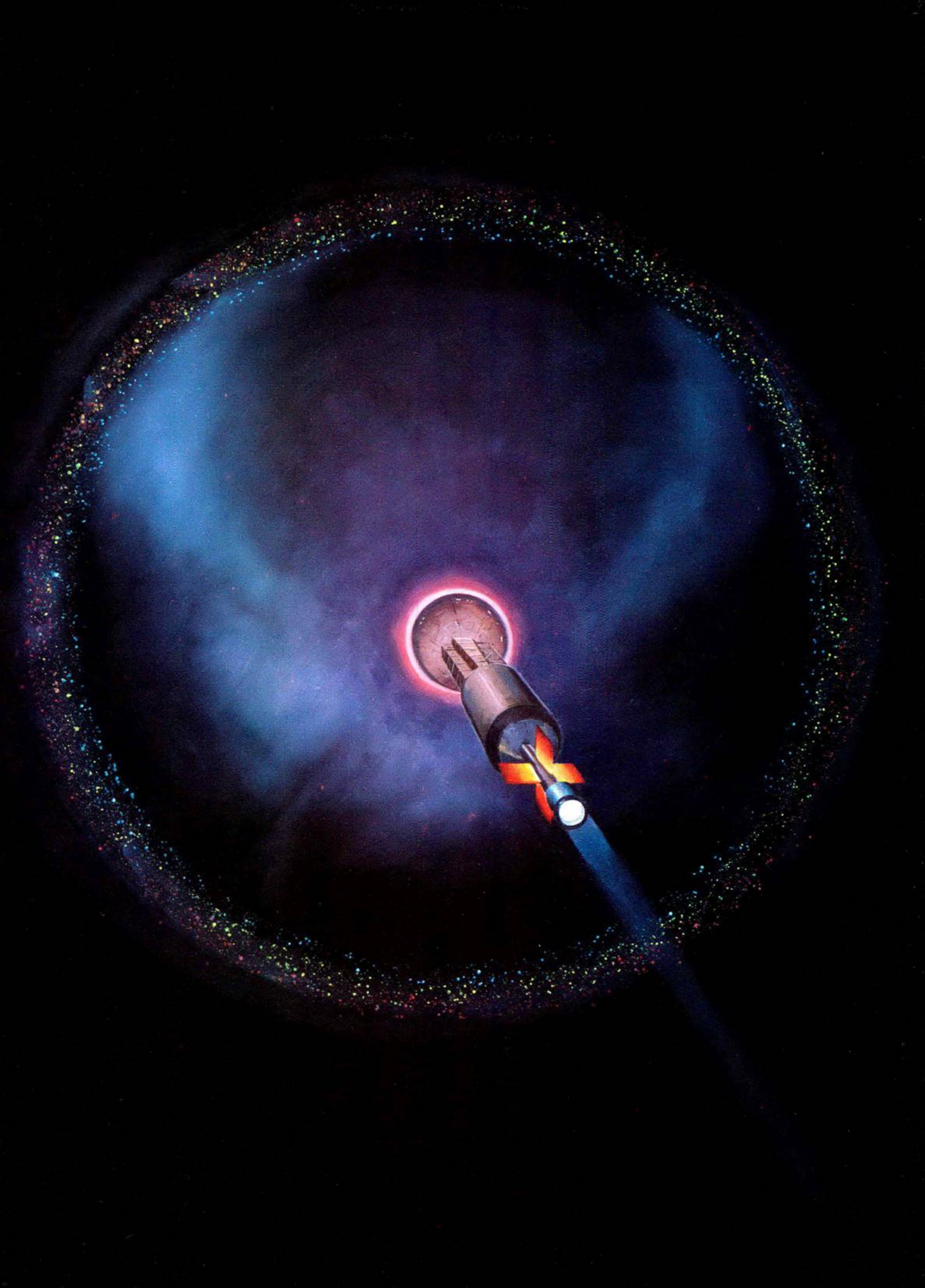
Somewhat more hypothetical — yet still possible, provided certain engineering breakthroughs are made in confining particles by electromagnetic fields — is the space ramjet. This starship's engine would scoop up interstellar hydrogen and compress it into a fusion reaction. The hydrogen would then be ejected at high speed to push the mass of the spaceship just as a jet engine ingests air, heats it and uses it to push an aircraft through the atmosphere.

A space ramjet might require a collecting field hundreds of miles in extent to funnel enough interstellar hydrogen into the engine. As the ship speeds up, a smaller field extent will be needed because the ram's efficiency increases at high velocities. An interstellar ramjet might weigh 100,000 tons, consisting mostly of payload.

Another engineering problem associated with all proposed propulsion schemes is that tremendous energies have to be controlled and utilized. Most of man's machines are very inefficient. Consequently much of the energy developed in propulsion is wasted by absorption into the vehicle or dissipation into space by radiators. Unless higher efficiencies can be obtained by starship drives, the problem of waste heat disposal may be insurmountable. Radiators based on current engineering practices are completely impractical, since they would have to be thousands of square miles in area.

As a ramjet propelled spaceship blazes starward at 99 percent the speed of light, all that remains of the visible universe is a narrow ring of stars — all other starlight has been shifted into invisible higher (ultraviolet, X-rays, etc.) and lower (microwave, radio, etc.) wavelengths by the vessel's tremendous velocity. Meanwhile, intense magnetic fields scoop up interstellar hydrogen to fuel the ship's fusion-powered engines. By "living off the land", such a starship would not have to drag along hundreds of thousands of tons of propellant.

Artwork by John Clark



Some interesting problems of navigation are connected with interstellar flight, but these are probably no more serious than the problems of interplanetary navigation discussed by spaceflight enthusiasts in the 1930s before the advent of the electronic digital computer. In those days one of the prime targets of the research group of the British Interplanetary Society was to develop an inertial system which is now a commonplace component of nearly every missile and of many aircraft. But in the 1930s, such basic navigation instruments had not been devised.

Because extremely high velocities distort starlight by both compressing and stretching its wavelengths, interstellar navigation is beset with problems similar to those faced by early space enthusiasts who tried to determine how spaceships might move under the influence of several gravitational fields. Today starship navigation appears hazardous and complex — but ways will be found to simplify its techniques.

As a starship reaches 30 percent of the speed of light, the navigator loses visible contact with the sun; its light has shifted completely into the infrared portion of the spectrum. Visually the navigator sees a black void widening behind the starship. As his spacecraft continues accelerating, the void spreads to engulf an expanding circle of reddening stars.

At a slightly higher velocity, the stars ahead shift color into the ultraviolet and become invisible to the unaided human eye. A number of previously invisible, low temperature red stars suddenly appear before "bluing" and winking out. As speed increases, all the stars ahead become increasingly bluer — progressively vanishing in a widening circle. As the ship continues accelerating, black voids to the front and rear engulf more and more stars — while the stars themselves seem to be trying to move out of the way of the spreading blackness by congregating into a barrel of light. At 75 percent of the speed of light, the whole star sphere contracts into a rainbow or "starbow" of stars ahead of the ship.

At 99 percent of the speed of light, this starbow even contracts into a narrow ring. Its utterly black center ahead of the starship forms a hole into which the starship heads at fantastic velocity. Without special instruments there can be no other visual reality in the observable universe.

The starship navigator should be able to measure his speed by the angle between the yellow ring within the starbow and the line of flight. But finding position is difficult since all the stars have shifted apparent position and no constellations can be recognized.

Should the navigator make an error and cause his starship to head out of the galaxy, the starbow becomes a prismatic crescent. If the bow disappears completely, the navigator could be in deep trouble. He has either exceeded the velocity of light or left the galaxy!

Other thoughts about how interstellar journeys might be accomplished are still very much in the realm of science fiction and are highly speculative.

* An inertial drive reacts with the mass of the universe to achieve a propulsive effect.

* A short cut through "hyperspace" (whatever that is) takes a starship from A to B without having to traverse the space in between — perhaps via a black hole.

* The starship and its crew are temporarily

SPACE ODYSSEYS AT NEAR LIGHT SPEEDS

Destination	**Distance (light-years)**	**Round Trip Elapse Time (years)**	
		on board starship	**on Earth**
Tau Ceti	12	10	24
Hyades star cluster	130	20	260
Orion nebula	1,600	30	3,200
Center of galaxy	27,000	40	54,000
Large Magellanic Cloud	155,000	50	310,000
Andromeda galaxy	2.25 million	60	4.5 million

The table demonstrates how time dilation could allow for reaching very distant objects within a human lifetime. It assumes that a starship accelerates at a uniform 1G, and coasts at 99.999 percent the speed of light.

(Adapted from Carl Sagan's "Direct Contact Among Galactic Civilizations by Relativistic Interstellar Spaceflight", **Planetary and Space Science**, 1963.)

Fantasy of Flight

"...all this stuff about traveling around the universe... belongs back where it came from, on the cereal box," remarked physicist Edward Purcell in 1960. Although interstellar travel appears awesomely complex by today's technological standards, Purcell and other critics should have learned a lesson from their shortsighted predecessors. The past echoes with the hollow pessimism of scientists who scoffed at and "disproved" the reality of air travel and spaceflight.

1910 — Astronomer William H. Pickering:

"The popular mind often pictures gigantic flying machines flying across the Atlantic.... It seems safe to say that such ideas must be wholly visionary, and even if a machine could get across... the expense would be prohibitive.... If with 30 h.p. (horse power) we can now attain a speed of 40 m.p.h., then in order to reach a speed of 100 m.p.h. we must use a motor capable of 470 h.p... it is clear that with our present devices there is no hope of competing for racing speed with either our locomotives or our automobiles."

1920 — **New York Times** *Editorial:*

"...after the rocket quits our air and really starts on its longer journey, its flight would be neither accelerated nor maintained by the explosion of the charges it then might have left. To claim that it would be is to deny a fundamental law of dynamics...."

1926 — Professor A. W. Bickerton:

"For a projectile to escape the gravitation of Earth, it needs a velocity of seven miles a second. The thermal energy of a gram at this speed is 15,180 calories.... The energy of our most violent explosive — nitroglycerine — is less than 1,500 calories per gram. Consequently, even had the explosion nothing to carry, it has only 1/10 of the energy necessary to escape Earth.... Hence the proposition appears to be basically impossible...."

1941 — Professor J. W. Campbell:

"While it is always dangerous to make a negative prediction, it would appear that the statement that rocket flight to the moon does not seem so remote as television did less than 100 years ago is overoptimistic."

1945 — Dr. Vannevar Bush:

"There has been a great deal said about a 3,000 mile high angle rocket... shot from one continent to another.... I say, technically, I don't think anyone in the world knows how to do such a thing, and I feel confident that it will not be done for a very long period of time to come."

converted into tachyons — particles that only travel faster than light. The hypothetical tachyons do not violate Einstein's physics, which simply states that matter doesn't travel *at* the speed of light. Some physicists imagine a universe separated by a light "wall" — with particles moving slower than light restricted on one side, and particles traveling faster than light always existing on the other side. The tachyon universe would be our mirror image, having the upside-down rule that the more energy a particle has, the slower (closer to light's velocity) it travels.

* People might be transmitted to distant stars as encoded elctromagnetic energy. The energy states and location of each subatomic particle making up a physical body might be scanned, identified and then transmitted at the speed of light. At the distant star system it would be reassembled as a duplicate, having all the characteristics of the original.

Nevertheless, the more conventional concepts of interstellar flight are basically no more difficult technically than was interplanetary flight in the early 1930s, when liquid rocket engines were no bigger than eggs and rarely lasted for more than a few seconds before exploding. But mankind may need the equivalent of the arms race and space race of the early 1960s to push it to the stars. Perhaps radio contact with extraterrestrial intelligences will be the motivation that will launch a national or international effort to man's destiny among the stars.

Eric Burgess is a member and was the first chairman of council of the British Interplanetary Society, and helped form the International Astronautical Federation. In 1949 he published the first technical paper on unmanned Earth satellites in synchronous orbits for scientific/communications purposes, and in 1951 wrote the first technical paper on a photo probe to Mars. More recently he originated the idea of sending a message to extraterrestrial intelligences via Pioneer 10.

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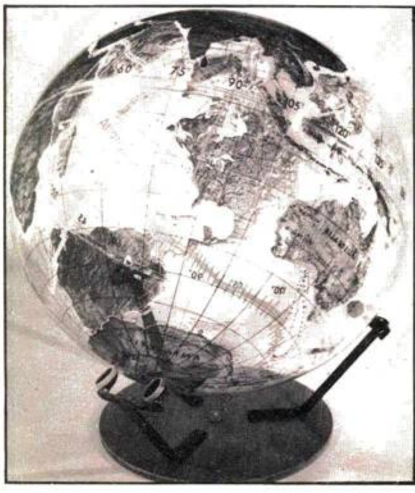

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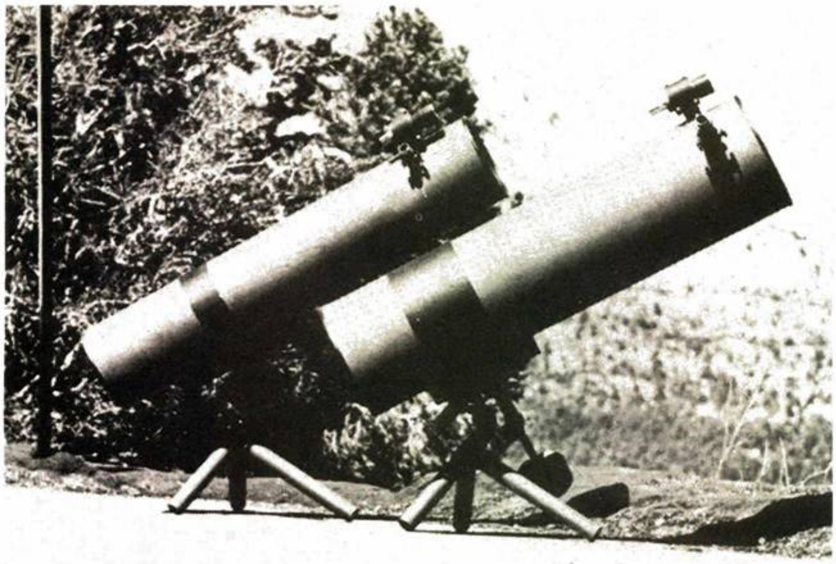

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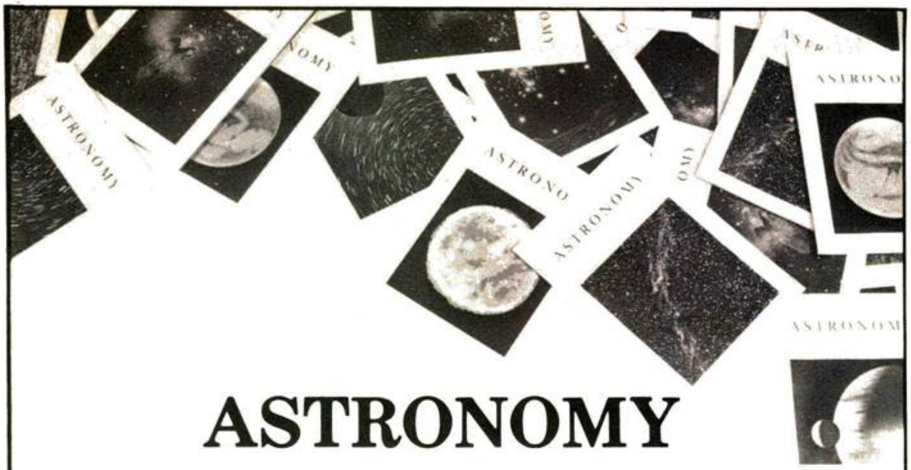

ASTRONOMY

Guide to Back Issues

Many readers continue to ask about the availability of ASTRONOMY back issues, but the majority blindly send us an order requesting issues we no longer have. For example, the October 1973 issue has been sold out for at least six months.

The following guide, which will be changed monthly, is designed to give you the most up-to-date information on the status of back issues. While they last, back issues are available for the cover price of $1.50 each (price includes postage).

When ordering, please clearly state quantity, volume, number, month and year for each issue (first issue was August 1973), and **include payment with your request.** If issues ordered are no longer available, unless you instruct us to forward a refund or substitute issues, we will automatically extend your subscription appropriately.

Vol. 1, No. 1 - August 1973	**Available**	**Vol. 2, No. 8 - August 1974**	**Depleted**
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Vol. 1, No. 3 - October 1973	**Depleted**	**Vol. 2, No. 10 - October 1974**	**Available**
Vol. 1, No. 4 - November 1973	**Depleted**	**Vol. 2, No. 11 - November 1974**	**Available**
Vol. 1, No. 5 - December 1973	**Depleted**	**Vol. 2, No. 12 - December 1974**	**Available**
Vol. 2, No. 1 - January 1974	**Short Supply**	**Vol. 3, No. 1 - January 1975**	**Available**
Vol. 2, No. 2 - February 1974	**Short Supply**	**Vol. 3, No. 2 - February 1975**	**Available**
Vol. 2, No. 3 - March 1974	**Available**	**Vol. 3, No. 3 - March 1975**	**Available**
Vol. 2, No. 4 - April 1974	**Available**	**Vol. 3, No. 4 - April 1975**	*** NYP**
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Vol. 2, No. 6 - June 1974	**Available**	**Vol. 3, No. 6 - June 1975**	*** NYP**
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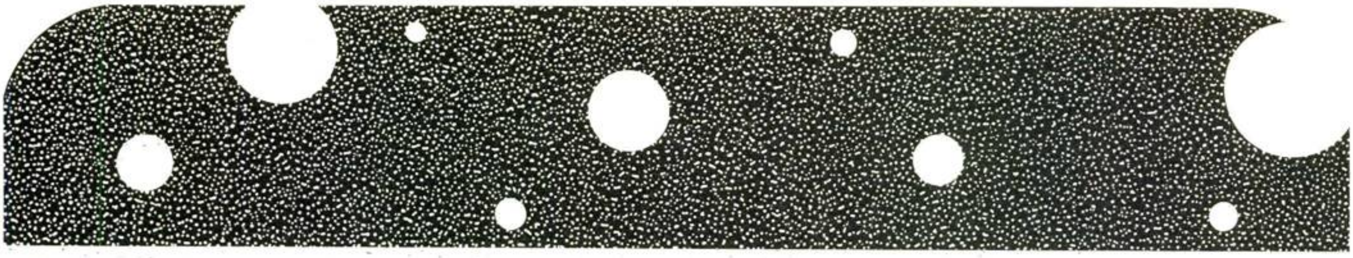


STELLAR FRONTIERS

Interstellar Molecules

by

Gerrit L. Verschuur

Although we normally think of the void between the stars as the coldest, darkest vacuum imaginable, it is actually littered with clouds of dust and gas and a tenuous distribution of hydrogen atoms. And, incredible as it may sound, chemical processes are occurring in these clouds.

In a random and tediously slow way, molecules of increasing complexity appear to be evolving in the depths of space. The search for their existence has become one of the most competitive areas of modern astronomical research, and over the last few years we have been flooded with discoveries of new interstellar molecules.

In the early 1940s, the first three interstellar molecules were identified: cyanogen (CN) and the unnamed CH and CH^+. (C refers to the carbon atom, N to nitrogen and H to hydrogen. When the single electron orbiting the hydrogen atom is stripped out of its orbit, the atom is "ionized" and the notation H^+ is used.) These three molecules were identified by the way they dim very definite wavelengths (or colors) of light from distant stars.

No new interstellar molecules were discovered until 1963 when the combination of the oxygen (O) and hydrogen (H) atoms, called simply OH, was detected because it emitted a radio signal at four characteristic wavelengths around 18cm. Radio astronomers studied this molecule in various dust and gas clouds in our Milky Way galaxy for another five years, not suspecting that there might be other more complex molecules out there in space. Then in 1968 the dam burst. Astronomers at the University of California made the startling discovery that there were interstellar clouds containing water (H_2O) and ammonia (NH_3). However, the radio signals from clouds of water were so strong that anyone could have found this molecule at least 15 years earlier — if only they had thought of looking for it!

Now, seven years after the discovery of the water and ammonia signals, astronomers have uncovered at least 34 different molecular species existing in clouds of interstellar gas and dust. Radio signals from at least three other as yet unidentified species have also been found.

The most fascinating findings show that chemistry in space is much like the chemistry taking place here on our planet — in particular the processes we call *organic chemistry.* Organic chemistry involves reactions of molecules containing carbon atoms — the underlying element behind all Earth life. Yet we find that events in the alien conditions of deep space also favor carbon chemistry above all else. Hydrogen cyanide, water, ammonia, methyl alcohol, and cyanoacetyline are among the recent organic discoveries. These discoveries have added greatly to the belief (now common among astronomers) that life is not a rare commodity in the universe.

Could the existence of space-born organic molecules speed up life's evolution on an Earthlike planet? If they do it would free us from trying to explain how the building blocks of life might instead form in a planet's atmosphere or oceans. This "cosmic seeding" concept has been hotly debated at recent

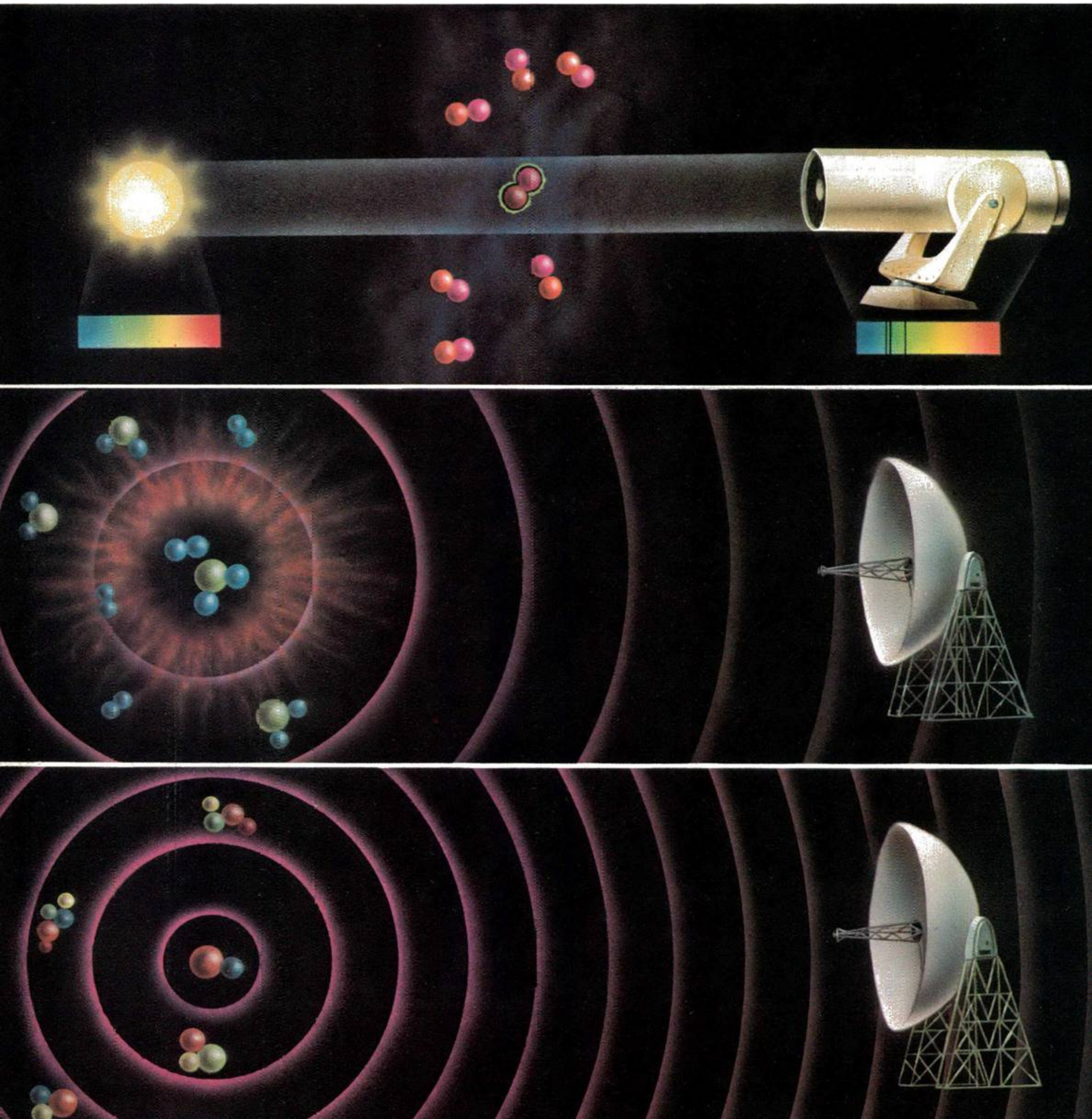
A mixture of organic molecules swirl into an embryonic planet of a newborn star within the Orion nebula. Created eons earlier in the cold vacuum of interstellar space, the molecules may survive to become the first building blocks of life on this new world. Although astronomers are far from linking interstellar organic molecules to life's genesis, their existence in space adds a new perspective to the question of the abundance of extraterrestrial life.

Artwork by Adolf Schaller

gatherings of astronomers. Some theorists believe all the organic chemistry within clouds of dust and gas are destroyed in the process of planetary formation. Certainly the energy released from a newly ignited star would break up any molecules remaining in the cloud of material it condensed from. But if the dust around the star's still-forming planets is sufficiently thick, these delicate molecules might be shielded from the destructive starlight.

Although the fate of interstellar organic molecules remains a mystery, their existence in such seemingly hostile conditions implies that life evolving elsewhere will likely be of a chemical form we can easily recognize. The conclusion is that carbon based life is probably commonplace throughout the galaxy.

So far, the most complex molecules have been found inhabiting a few unique clouds in the galaxy. One cloud lies within the Orion nebula and the other hides behind enormous amounts of dust in the direction of the center of the Milky Way. At present, whenever astronomers want to look for new molecules in space, they first search these two locations. Although many other equally interesting



clouds likely drift in the galaxy, they have yet to be found.

Detailed studies of these clouds by instruments sensitive to infrared light reveal very young, hot objects which might be stars almost ready to start burning their hydrogen through nuclear fusion. Some of these embryonic stars are surrounded by dense shells of dust and gas that may also contain complex molecules. Hopefully the star doesn't disintegrate all of this rich organic soup as solar wind sweeps leftover debris away from the freshly completed solar system.

Simpler molecules such as hydroxyl, formaldehyde and carbon monoxide not only exist in dense dust clouds shrouding star formation but are also seen spreading throughout the Milky Way galaxy. While these molecules are still associated with dust they are found in the less dusty regions between the stars.

Why the molecules form is still unknown since processes in the vacuum of space cannot be duplicated in the laboratory. In the lab we can mix gases and shine ultraviolet light or flash electric sparks through the solution and watch complex molecules grow quite rapidly. In space, however, atoms are so much more thinly spread that they hardly ever bump into each other and therefore do not get a chance to stick together and form molecules. Some molecules may be created by atoms colliding with dust particles (whose nature is also unknown). The dust particle collects lots of hitchhiking atoms and simple molecules which then combine on the surface of the particle building bigger molecules. The complex molecules get driven off the dust particle to wander freely through space — allowing us to pick up their radiation.

Another process of molecule formation involves the effects of cosmic ray particles stripping electrons out of their atomic orbits. The resulting ions readily combine with other ions and ultimately, when the electrons are captured again, larger molecules are built up. These processes are all part of the new science of astrochemistry — one of the most exciting branches of astronomy research today.

Which molecules will likely be discovered next? Astronomers expect to find a logical sequence of molecules, and systematic searches are under way. For example, the discovery of ethyl alcohol, an important link in the chain of molecular formation, was recently announced (see Astro-News, January 1975). Soon the presence of heavy water (HDO) will also be revealed. Much attention is focusing on the search for amino acids, the basic components of protein. Amino acids have already been found in meteorites, but confirming their existence in the far reaches of our galaxy will give astronomers valuable new evidence in the case for extraterrestrial life.

INTERSTELLAR MOLECULES

Molecule	Common Name	Year Discovered
CN	Unnamed	1937
CH	Cyanogen	1940
CH^+	Unnamed	1941
OH	Hydroxyl	1963
H_2O	Water	1968
NH_3	Ammonia	1968
H_2CO	*Formaldehyde	1969
CO	*Carbon monoxide	1970
H_2	Hydrogen	1970
HCN	*Hydrogen cyanide	1970
?	X-Ogen	1970
HC_3N	*Cyanoacetylene	1970
CH_3OH	*Methyl alcohol	1970
HCOOH	*Formic acid	1970
CS	Carbon monosulphide	1971
NH_2COH	*Formamide	1971
SiO	Silicon monoxide	1971
CH_3CN	*Acetonitrile	1971
OCS	Carbonyl sulphide	1971
HNCO	*Isocyanic acid	1971
HNC	Hydrogen isocyanide	1971
CH_3CCH	Methylacetylene	1971
CH_3CHO	*Acetaldehyde	1971
H_2CS	Thioformaldehyde	1972
H_2S	Hydrogen sulphide	1972
CH_2NH	Methanimine	1972
SO	Sulfur monoxide	1973
HD	Unnamed	1973
DCN	Unnamed	1973
$(CH_3)_2O$	Dimethyl ether	1974
CH_3NH_2	Methylamine	1974
CH_2CHCN	Vinyl cyanide	1974
CCH	Acetylene radical	1974
N_2H^+	Unnamed	1974
SiS	Silicon sulphide	1974
CH_3CH_2OH	Ethyl alcohol	1974
HDO	Heavy water	1974

Plus at least three unidentified species.

***These molecules have also been produced in the laboratory and are considered to be among the basic building blocks of life.**

Interstellar molecules can be detected in various wavelengths including visible light and radio. Diagram A shows a cyanogen molecule absorbing a specific set of wavelengths from starlight. On Earth the molecule's "fingerprints" show up as dark absorption lines imprinted on the star's spectrum. In B, a collision between a water molecule and molecular hydrogen triggers a weak radio emission. This electromagnetic "ouch" shows up as a unique radio frequency identifying the molecule. In diagram C, electrons within atoms of a hydroxyl molecule randomly reverse their orbital direction making a small change in the molecule's overall energy level. These continuous shifts in energy release a special set of radio frequencies.

Artwork by Victor Costanzo

New From Astronomy

The 1975 Trifid Calendar

1975 has arrived. And in keeping with ASTRONOMY's Orion Calendar of last year, we've designed an even more unique calendar wall poster.

This beautiful 22 x 34 inch poster shows a blowup view of the Trifid nebula — one of the most colorful jewels of the universe — in the constellation Sagittarius. The photograph — one of the sparkling, new color photographs from Kitt Peak National Observatory — has never been published this large before. Gossamer shadings of red and blue draw your mind into the depths of the awesome universe.

Surrounding the photograph are 12 sky maps, one for each month of the year — making the 1975 Trifid Calendar not only beautiful but doubly useful. At the end of the year, all you have to do is cut off the calendar portion — and you will have a wall hanging of lasting beauty and value.

This lithographed reproduction is printed on heavy gloss paper and has a protective varnish coating. And to insure that the Trifid Calendar reaches you in A-1 condition, it will be rolled — not folded — and shipped to you in a mailing tube via first class mail.

Price: $3.75 each (includes first class postage)

Sorry — calendars may not be billed.

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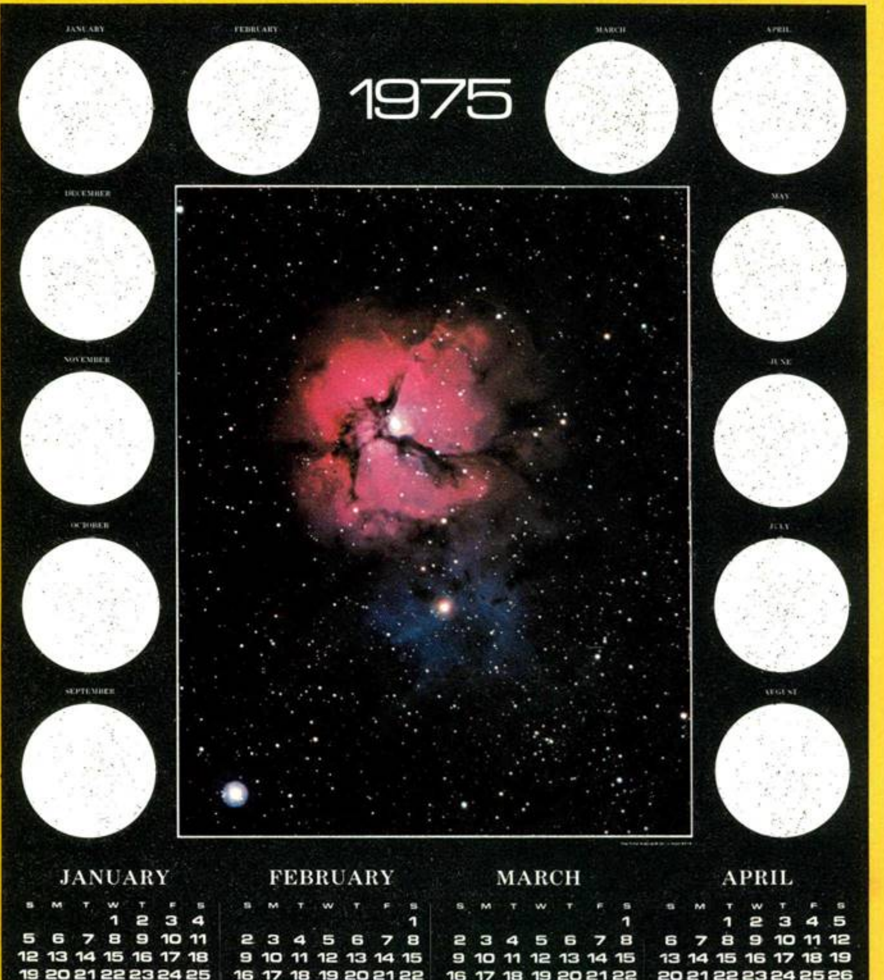

JANUARY

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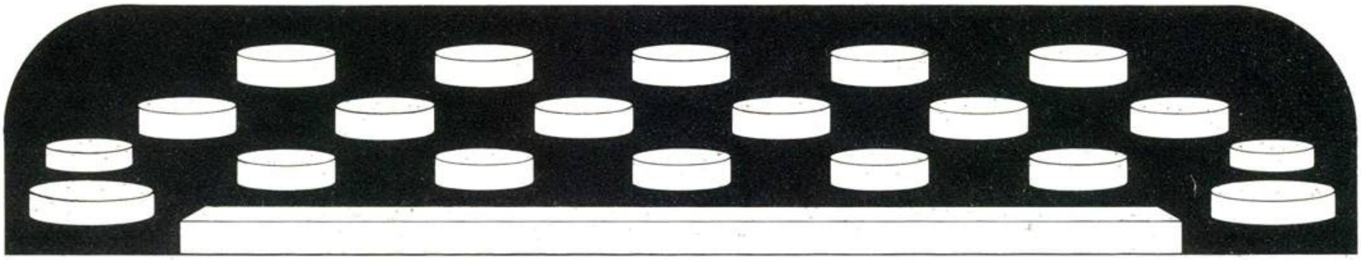


IN FOCUS

Sir / I would like to commend you for your excellent astronomy magazine. In particular, I would like to acknowledge the beautiful diversity of your articles, the compact up-to-date information in Astro-News and the honest and helpful astronomy book reviews. The magazine would make an excellent resource for students in my introductory astronomy courses!

I would like to request that you continue to change as you have in the past, since each change has improved your magazine.

GEORGE REED
West Chester State College
West Chester, Pa.

Sir / "The Zeta Reticuli Incident" was the best article your magazine has published. The articles always are good to excellent, but this one was a "mind blower" in its wealth of detail, amount of research and collecting of the work of various researchers, and the way it answered some of my "unanswerable" questions about solar position in the galaxy in reference to nearby stars.

The cover is glorious!

ALAN BOWMAN
Berkeley, Calif.

Sir / You have a good magazine — just the type of reading that I enjoy! But am I reading you correctly? In that great article on Jupiter (page 10, November 1974), you say — 54,000 degrees — six times hotter than the surface of the sun. That makes the sun's temperature 9,000 degrees. Correct?

PAUL HOFFMAN, D.D.S.
Bethesda, Md.

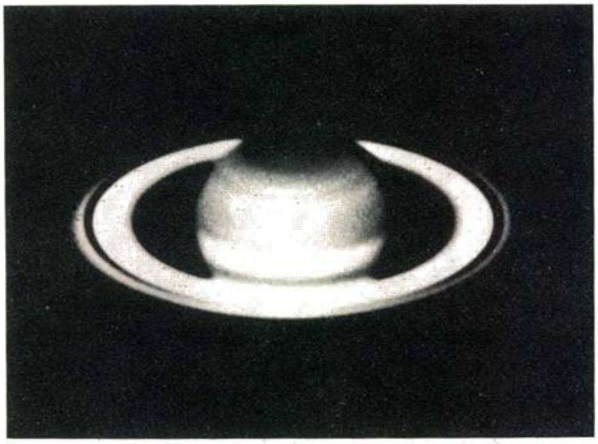
Dear Dr. Hoffman / Yes, the comparison is correct. The sun's surface temperature is about 11,000 degrees Fahrenheit. However, the sun's central temperature is 30 million degrees — hot enough for thermonuclear reactions.

Sir / In the October 1974 issue (page 35), you ask of Jupiter's Red Spot: "Can the spot be clearly seen in a 2.4 inch refractor?" I have a two inch refractor mounted on my six inch reflector. I use the six inch for observing and making drawings of Jupiter, but occasionally look through the two inch. The Red Spot can be recognized at 50 power in the two inch.

FRANK F. PENTZ
Reading, Pa.

Sir / I recently gave my opinion of your magazine in your very thorough survey, but I would like to take this opportunity to personally thank you for printing the finest astronomy magazine ever. In fact, it's the only magazine I've ever read from cover-to-cover consistently. I hope the quality of your magazine never diminishes. Thanks again.

GEORGE TAYLOR
Modesto, Calif.



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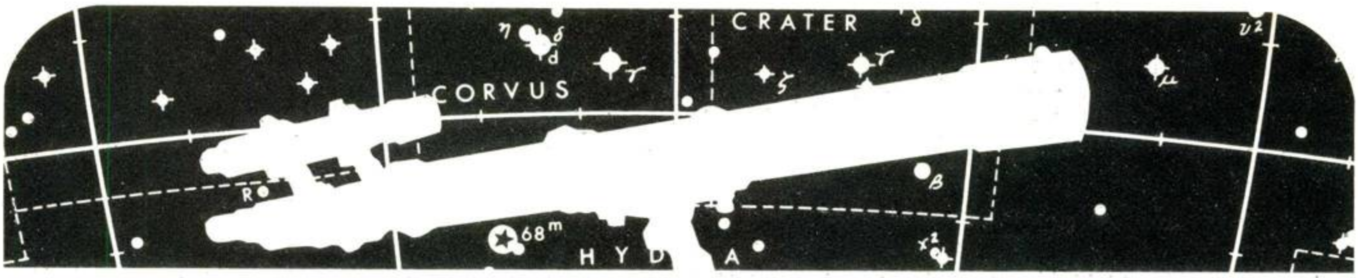


EQUIPMENT ATLAS

The Eyepiece

by Thomas C. Bretl

The objective lens or primary mirror of a telescope is often called its heart — and rightfully so. But eyepieces also have a very important function. Unknowingly you could be operating your telescope far below its potential by using an inferior eyepiece or one that is not well suited to your particular instrument.

It is possible that your telescope did not come equipped with the eyepieces best suited to its performance capabilities. This is an area where some manufacturers (or you, yourself, if you selected your own eyepieces) skimp to cut equipment costs. On the other hand, even the finest eyepieces will not significantly improve the view if your telescope has a mediocre objective lens or mirror.

To help you evaluate the best telescope/eyepiece combinations, let's take a detailed look at eyepieces to see how they work, why they work, and what qualities make some of them better than others.

Children often ask how much closer a telescope "makes" things. To them, it is a marvelous instrument capable of physically bringing objects nearer to us — perhaps through some sort of magic. This point of view, although seemingly naive, is actually a very accurate one. A telescope doesn't literally "move" anything, of course — but it does form images of objects and then allows us to move our eyes close to those images. It is the function of the objective lens or primary mirror to form the image while the eyepiece allows us to get very close to that image. It works this way:

A telescope is basically a combination of camera and magnifying glass. Like a camera lens, the objective lens forms "real" images — images that could be recorded on photographic film — while the eyepiece, working exactly like a magnifying glass, allows us to bring our eyes much nearer to these images than we normally could. The diagram on page 44 shows how a magnifying glass works. The glass, a simple convex lens, bends the light rays coming from the object in such a way that they appear to be coming from a larger and more distant source called the *virtual image*. The shorter the focal length of the lens, the closer the object is placed in front of it and the more sharply the lens "bends" the light rays. The net result of all this bending is that the virtual image appears as large to our eyes (that is, it subtends the same angle) as the actual object would if the lens were removed. The virtual image, however, is far enough away to permit our eyes to focus upon it clearly — while the real object would be much closer to our eyes for proper focusing were it not for the intervening lens. Thus, by making it seem farther away but at the same time larger, a magnifying glass lets us get very "close" to things.

In a telescope, the eyepiece does the job of the magnifying glass. The object for the eyepiece is the image formed directly in front of it by the primary mirror or objective lens. The eyepiece makes this image appear larger in exactly the same way as a magnifying glass makes a real object appear larger. Essentially, it is the same as taking a photograph and then using a magnifying glass to examine the resulting print — but in this case the film is left out and the image is examined directly from the other side. On page 44 we see the entire situation: An objective lens is shown forming the image of a candle, while the eyepiece behind it "enlarges" that image.

Magnification

When the telescope in the diagram is focused sharply, the distance separating the single lens eyepiece from the image formed by the objective is almost exactly equal to the focal length of the eyepiece lens. Thus, the shorter the focal length of that lens, the closer the observer's eye is to the image and the greater the magnification. The eyepiece alone, however, does not tell the whole story; the objective lens also plays an important role. Like a camera lens, the longer the focal length of the objective, the larger the image it produces; it is that image that the eyepiece magnifies even more.

The magnifying contributions of both the objective and the eyepiece combine quite simply into a brief equation: $M = \frac{F_o}{F_e}$. This equation gives the total magnification (M) in terms of the focal length of the objective (F_o) and the focal length of the eyepiece (F_e). For example: A small refractor's objective has a 30 inch focal length which, according to the

An array of eyepieces — far more than any astronomy enthusiast would ever need — are displayed here for comparison. At first glance many may look alike, but depending on their optical configuration and focal length, some will perform better than others in your telescope. The tubular devices are Barlows which are used to effectively increase the telescope's focal length and thereby double to triple the magnification achieved with a particular eyepiece.

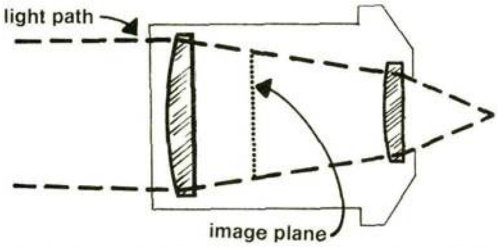
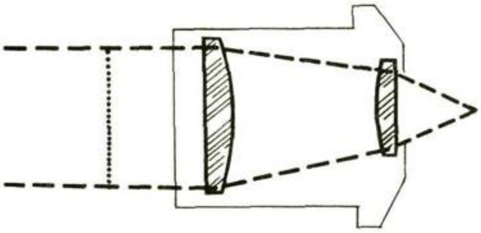
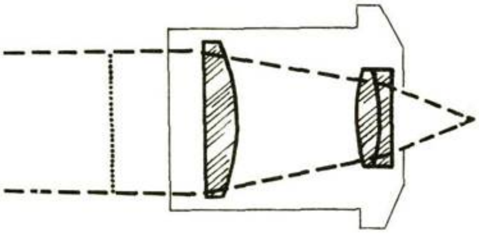
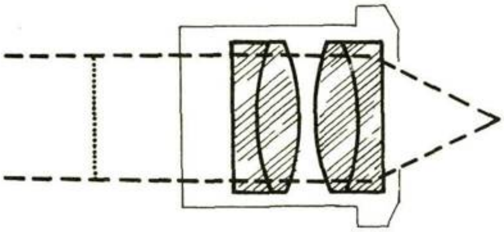
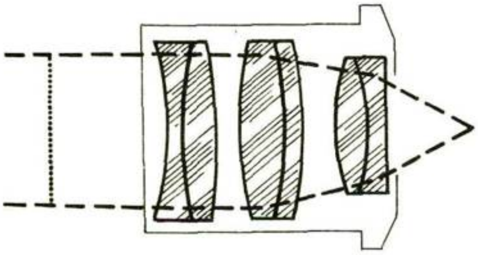
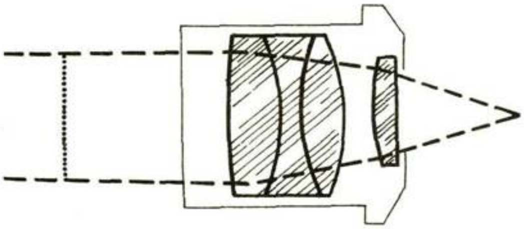
equation, yields a magnification of 30 when used with a one inch eyepiece, and 60 when used with a 1/2 inch eyepiece.

When looking at the equation, it would seem that there is an unlimited range of possible telescope magnifications. To get any desired magnification it should only be necessary to use an eyepiece with the appropriate focal length. In practice, however, this is not the case. An upper limit to magnification is set by the diameter of the objective lens (and the wave nature of light), while a lower limit is set by the size of the light collecting part of the human eye. The eyepiece itself is responsible for neither of these limits — but to be useful it must yield a magnification that falls somewhere in between them.

When a telescope is "pushed" to a magnification greater than 40 or 50 times its aperture in inches, the quality of the view is never improved. Like an extreme photographic enlargement, the image is bigger — but at the same time considerably less distinct. This "fuzziness" is due to the nature of light itself, and no eyepiece — regardless of its quality — can make it go away. The only solution is the use of a larger telescope.

On the other hand, when a very low magnification of less than three or four times the aperture in inches is used, a considerable amount of the telescope's precious light gathering power can actually be lost. To see why this is so, take another look at the diagram on page 44. You will notice that there is a place just behind the eyepiece where all the light rays come closest together. This marks the location of the *exit pupil*. Let's say a power of 25 is used on an eight inch telescope. This magnification — about three times the instrument's aperture — results in an exit pupil fully 1/3 inch wide. Since the pupil of the human eye is not able to open that wide, some of the light is lost. The practical lower limit is usually considered to be four times the scope's aperture in inches.

EYEPIECE

Type	Optical arrangement	Most functional focal lengths	Price range
HUYGENIAN		18 to 40mm	\$5 to \$15
RAMSDEN		12 to 30mm	\$5 to \$15
KELLNER		9 to 60mm	\$10 to \$30
SYMMETRICAL		18 to 40mm	\$10 to \$30
ERFLE		16 to 40mm	\$25 to \$75
ORTHOSCOPIC		5 to 25mm	\$20 to \$40

FACT SHEET

Best suited for	Advantages	Disadvantages	Comments
small refractors	definition excellent at center of field; inexpensive	short eye relief; edge of field definition poor with telescopes under f/10; poor performance in focal lengths under 18mm	identified by H., H.M., or A.H. engraved on exterior
small reflectors of long f-ratio	inexpensive	color problems with refractors; short eye relief and narrow apparent field especially in focal lengths under 12mm	identified by R., or A.R.
all scopes over f/6	better eye relief; wider field of view and better overall image quality than above	ghost images on bright objects; not as comfortable to use as orthoscopic at focal lengths under 12mm	identified by K.; a "best buy" for most telescope users
all scopes over f/6	comfortable to use since eye is well back from lens surface; excellent definition over entire field; generally economical	slight ghost images	
all scopes except small refractors	best for low power, wide field viewing; excellent for rich field telescopes	light loss is the greatest of all types due to absorption by multiple lenses; edge of field aberrations common and unavoidable; expensive	find out if a drawtube adaptor is needed before you buy
all scopes	best for high power viewing; good definition over entire field at all focal lengths	sometimes does not outperform good quality, less complex eyepieces at medium focal lengths	generally considered the top all-purpose eyepiece

Eyepiece Aberrations

If you use a simple convex lens as a magnifying glass and observe an ordinary piece of lined notebook paper, you will notice several prominent defects in the image. When the lens is positioned so that the center of the field is focused sharply, the lines near the edge of the field will appear bent, fringed with color, and somewhat fuzzy. (Field refers to *field of view* — the term applied to the entire visible area seen in an eyepiece. Field sizes vary from one eyepiece to another as will be discussed in detail next month.)

Some of these aberrations are probably present to some extent in your telescope. You can see them by setting up your instrument outside and focusing on a roof or wall of a distant building that has bright sky behind it. The main purpose here is to get a straight dark line against a bright background. Have the roof edge bisect the field of view. Now move the telescope so that the roof line is taken to the edge of the field and back again.

Do unreal colors become visible on the roof line when it is near the edge of the field? If so, your optical system is exhibiting *chromatic difference of magnification.* Try your other eyepieces. If they all have it, your telescope objective may be the source. If the spurious color is also apparent at the center of the field, then the defect is *chromatic aberration* whose source is either the objective or the eyepiece. Most refracting telescopes have chromatic aberrations, and in small doses it is not objectionable.

Does the roof line curve as it approaches the edge of the field? This is *distortion* and is not serious unless it is accompanied by a loss of focus. Edge of field loss of focus is caused by a defect in the eyepiece called *curvature of field.* It is almost impossible to avoid this problem in wide field eyepieces. A similar defect called *coma* is inherent in telescopes under f/5 unless they are extremely complex in design.

All of these aberrations — which in exaggerated degrees plagued telescopes of earlier generations — have over the years been virtually eliminated by the addition of complementing correcting lenses into the optical system. If both the eyepiece and the objective lens or mirror are manufactured to well-known but exacting specifications, the result will be satisfying images with a minimum — or sometimes no — aberrations.

The comments in the following section and in the table on pages 42 and 43 are offered as a *general* guide based on the experience of ASTRONOMY's editors. There are good and bad examples of each type of eyepiece and our analysis is based on what we feel are the characteristics of the *average* commercially available eyepiece of each type.

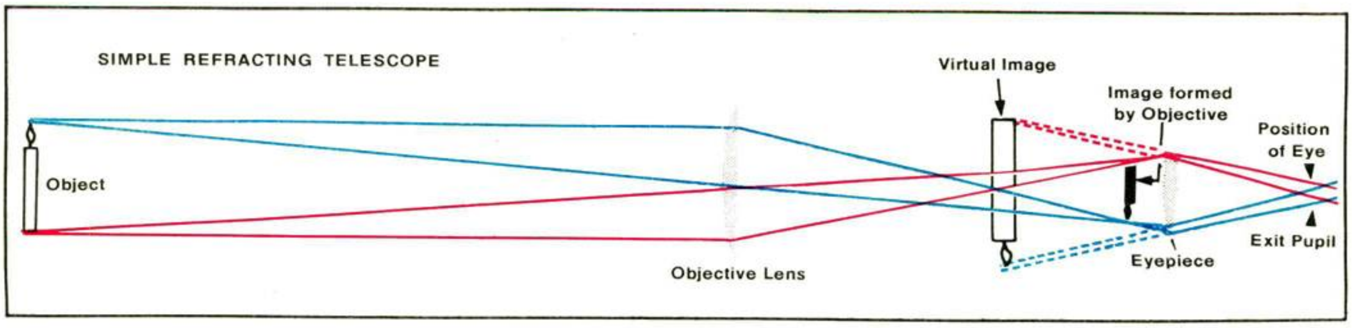
Types of Eyepieces

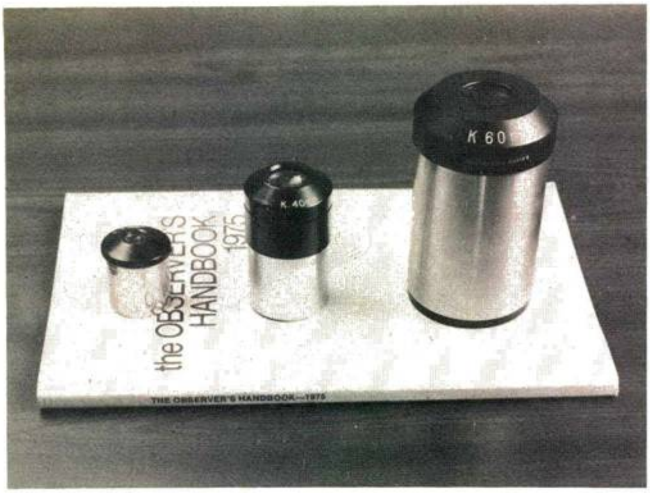
The earliest multiple element eyepiece that is still in use today is the *Huygenian,* constructed during the 17th century by the brilliant scientist and inventor Christian Huygens. It consists of two simple plano-convex lenses which are spaced in such a way that the real image of the object forms somewhere in between them (see illustration, page 42). The advantage of this eyepiece is that it eliminates chromatic aberration almost entirely while remaining fairly free of most of the other defects as well. Unfortunately, however, it is uncorrected for *spherical aberration* — a defect which is much more pronounced in telescopes of short focal ratio.

In the *Ramsden* eyepiece, another two-lens design, the lenses are mounted closer together and the real image forms just in front of the field lens. This arrangement is not as good as the Huygenian at eliminating chromatic aberration, but it is fairly well corrected for other defects including spherical aberration. Thus, it is a much better choice for use with most reflecting telescopes. Some people may find the Ramsden difficult to use because of its small "eye relief"; the exit pupil is located just behind the eye lens, and unless the observer positions his eye very close to that spot, he will be unable to see the full field of view. This can be annoying, especially for those who wear glasses.

The *Kellner* eyepiece is of the same basic design as the Ramsden, but color problems are eliminated in it by use of an achromatic eye lens. It has a wide field of view, is relatively free of aberrations, and is an excellent eyepiece for use with almost all types of telescopes. It often shows ghost images of bright stars or planets (caused by internal reflections off the lens surfaces), but this trait rarely spoils the overall quality of the view.

The *symmetrical* eyepiece is, like the Kellner, a good all-purpose medium power eyepiece. It consists of a pair of identical lenses in contact. A superb





Eyepieces are available in three main barrel diameters. Most telescopes accept only one size but some have adaptors for the use of two sizes. The most widely used size is the 1-1/4 inch diameter (center). Almost all Newtonian reflectors accommodate this size. The 0.96 inch size (left) is used almost exclusively on small refractors. For low power views on larger instruments (over six inches aperture), the two inch supersize is needed. Most larger telescopes can have their drawtube and/or focusing mechanism replaced with a larger size to accommodate both 1-1/4 inch and 2 inch eyepieces.

— and expensive — variation on the symmetrical design is the *Ploessl* (not listed on our table). The Ploessl has a pair of identical lenses spaced in a precise manner that gives unexcelled performance. Because of their expense, Ploessl eyepieces usually do not end up in the amateur's eyepiece rack. If you have a chance to buy a used one, get it. (In general, it is hard to damage an eyepiece other than by scratching the exposed lenses; durability makes most secondhand eyepieces a good buy.)

The *Erfle* has been described as "the amateur's window to the universe". On practically any telescope this type of eyepiece gives breathtaking low power, wide field views of the sky — especially of the Milky Way. Owners of Newtonian reflectors usually prefer an Erfle as their low power eyepiece. Unfortunately a price is paid for the wide field of view: The edge of field is often distorted and ghosting is common.

Similar in characteristics to the Erfle is the *Koenig* eyepiece. Although not listed on our table because it is not as widely used as the others, it is a superb design and gives excellent performance.

The word *orthoscopic* literally means "correct image", and that is exactly what a well-made orthoscopic eyepiece has to offer. Unlike the Kellner, it contains a simple convex eye lens with all its inherent aberrations — but this is matched with a three-element field lens possessing exactly opposite defects. Together, these lenses form an image that is almost totally free of all aberrations.

The Barlow

Some telescopes come equipped with a strange tubular "eyepiece" that has only one lens in it. This accessory (not an eyepiece) is called a *Barlow* or sometimes a *Barlow lens*, and many telescope users would not be without one. Depending on its construction, the Barlow can double to triple the power of all your eyepieces. When placed in the telescope drawtube between the eyepiece and the main lens or mirror, the Barlow effectively increases the focal length of the telescope and thereby increases the magnification. An f/7 reflector "becomes" an f/14 telescope with a two power Barlow, and f/21 with a three power Barlow.

At such long telescope focal lengths, an inexpensive low power eyepiece gains new versatility. For example, a 25mm (one inch) Huygenian that exhibits spherical aberration on an f/7 instrument would show little at f/14 and probably none at f/21. The use of a Barlow increases the eye relief of all eyepieces — a welcome benefit in many instances.

There are few disadvantages that accompany the use of a Barlow. The added lens in the optical system does absorb some light but this is generally not significant. The main thing to be aware of is the abysmal quality of some inexpensive Barlows. Quite often an economical eyepiece will give satisfactory performance, but such eyepieces are usually low power. However, a Barlow is always used for high power work and minor imperfections are disastrous. When you buy a Barlow, get the best.

Selecting Eyepieces

As a general rule, the larger the telescope, the better the eyepiece it requires (and deserves). If possible, actually try out a particular kind of eyepiece with your telescope before you decide to buy it or make sure the manufacturer offers a money back guarantee.

Perhaps the worst "eyepiece temptation" of all is to use too much magnification. We keep mentioning this point but high power is often the beginner's folly. It is only on rare nights of excellent seeing that you will be able to use an eyepiece magnifying 40 times the telescope's aperture in inches.

What is a good starting set of eyepieces? Here are some minimum recommendations: For a small refractor we suggest a 25 to 35mm Huygenian, a 12 to 20mm Kellner, and a 6 to 9mm orthoscopic. For a small Newtonian reflector a 25 or 35mm Ramsden or Kellner, a 12 to 20mm orthoscopic and a three power Barlow might be a good combination. For a larger (6 to 10 inch) Newtonian, a 30 to 40mm Erfle or Kellner, an 18 to 25mm orthoscopic or Kellner, and a 9 to 16mm orthoscopic or other high quality eyepiece might be combined with a good Barlow for a versatile performance team. In Schmidt-Cassegrain, Maksutov and Cassegrain telescopes, Kellners (low powers) and orthoscopics (higher powers) are good performers. Your individual preference based on experience will soon lead you to the ideal combination for your telescope.

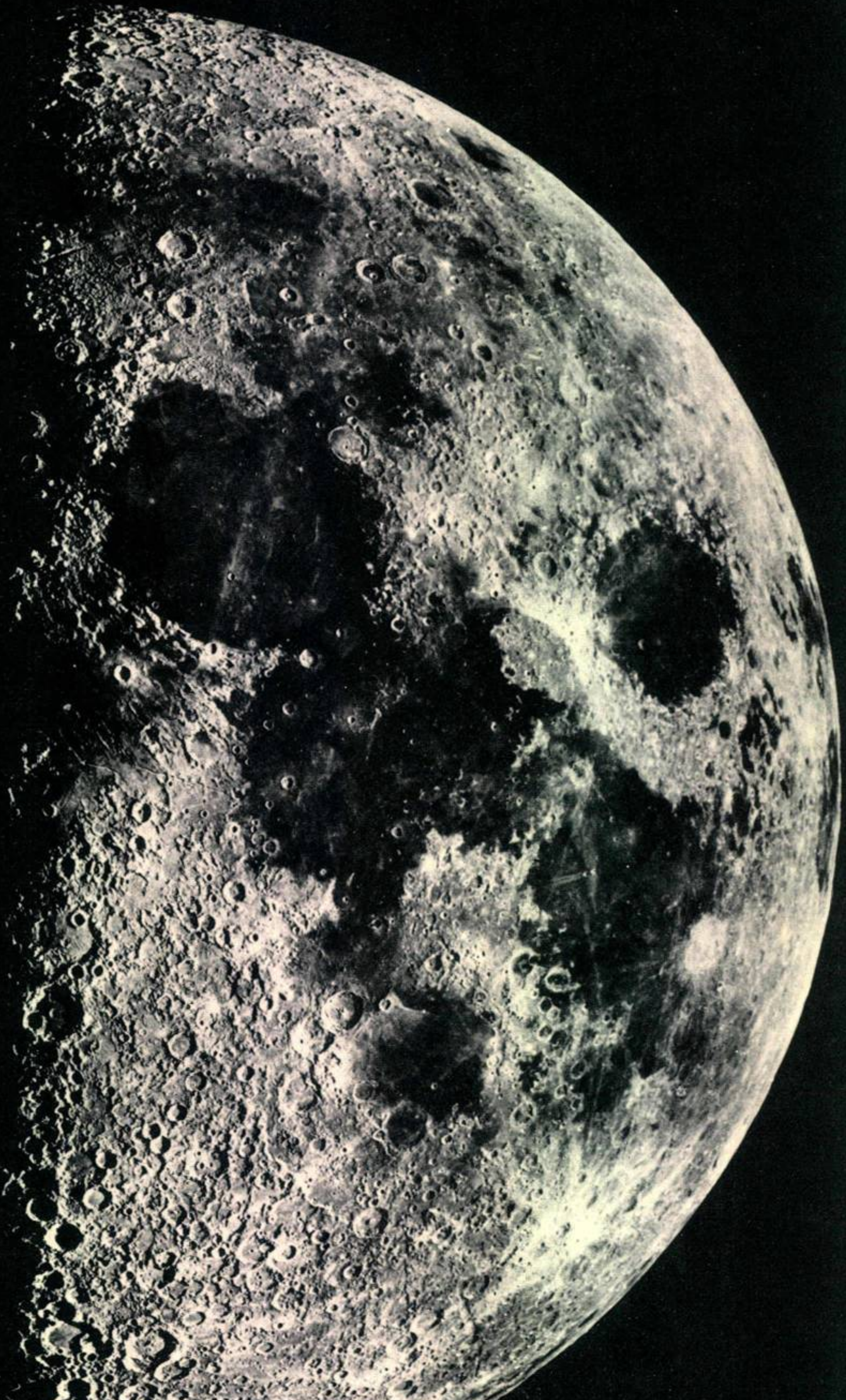
Do You Observe the Moon Anymore?

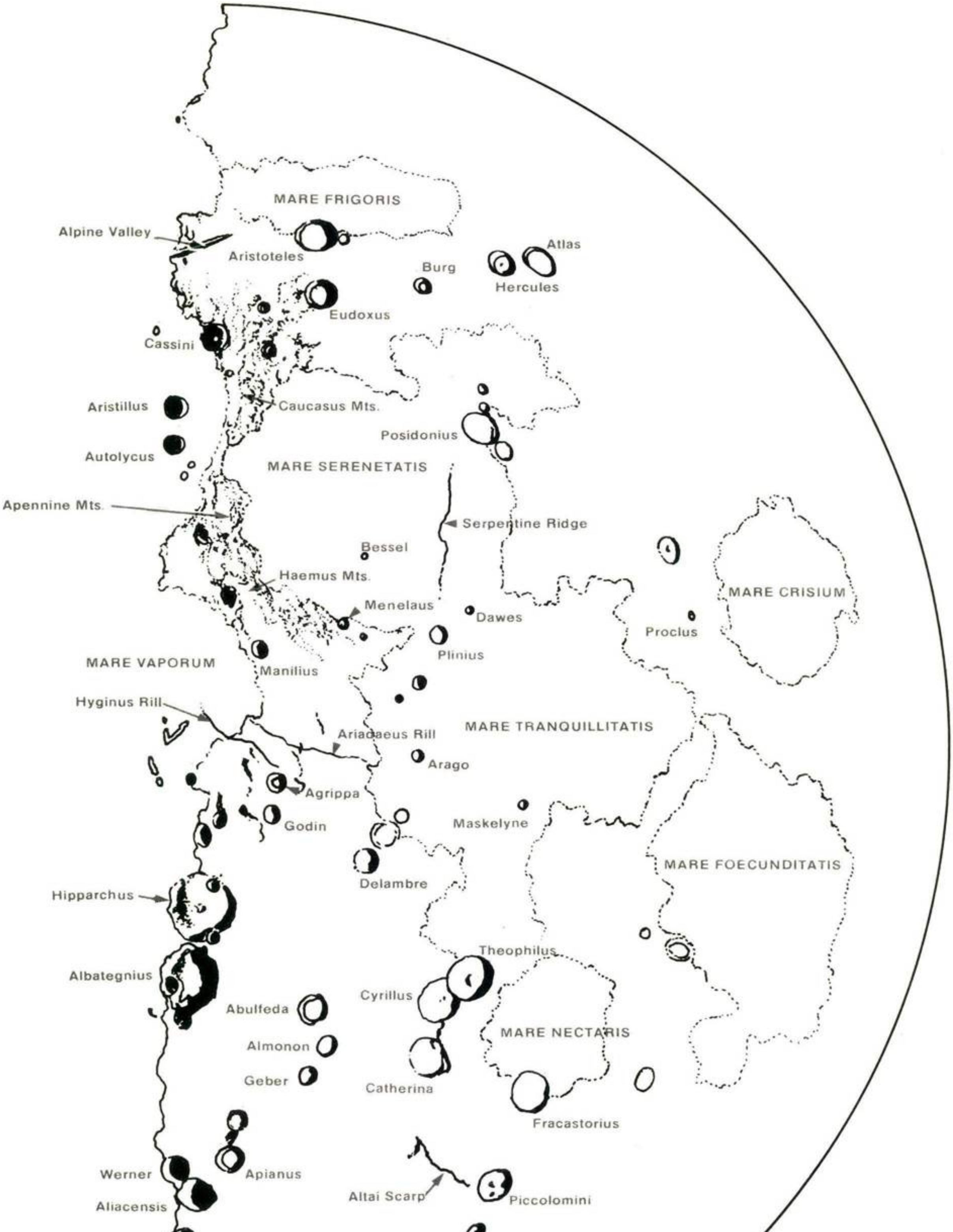
Hardly anyone goes sightseeing in their own city. We can always go to the museum or the zoo some other day — and so we never do. Somehow, exploring things that are nearby and easy to get to seems uninteresting and lacks challenge. Yet as soon as we get the opportunity to travel we don't waste any time taking in one tourist attraction after another. This effort seems to intensify the farther we are from home; the harder a place is to get to, the more we make sure we see what's worth seeing when we are there.

Near first quarter phase, the shadow-filled craters near the moon's terminator contrast with the brilliantly illuminated lunar "highlands". The detail revealed in this photo should be visible in a two inch telescope. An eight inch Celestron telescope was used for this exposure on Kodak SO-456 film. This film has extreme resolution with a slight bluish cast.

Photograph by John Sanford

The same sequence usually holds true for the typical astronomy enthusiast. On about half of the nights of the month, the moon rides high in the sky beckoning us to turn our telescopes toward its rugged face. But somehow it's just too easy, too ordinary...nothing exotic about the old moon. "Let's take a look at Saturn or the Great nebula in Orion," we say.




MARE FRIGORIS
Alpine Valley
Aristoteles
Atlas
Burg
Hercules
Eudoxus
Cassini
Aristillus
Caucasus Mts.
Posidonius
Autolycus
MARE SERENETATIS
Apennine Mts.
Serpentine Ridge
Bessel
Haemus Mts.
MARE CRISIUM
Menelaus
Dawes
Proclus
Plinius
MARE VAPORUM
Manilius
Hyginus Rill
Ariadaeus Rill
MARE TRANQUILLITATIS
Arago
Agrippa
Godin
Maskelyne
Delambre
MARE FOECUNDITATIS
Hipparchus
Theophilus
Albategnius
Cyrillus
Abulfeda
MARE NECTARIS
Almonon
Geber
Catherina
Fracastorius
Werner
Apianus
Altai Scarp
Piccolomini
Aliacensis
Maurolycus
Stofler

← Lick Observatory Photograph

Artwork by Victor Costanzo

Or perhaps there's another reason why the moon is often ignored: We know exactly what it is like. The mystery was removed by the men of Apollo. We watched them on television describing (sometimes in excruciating detail) the nature of the lunar soil and the structure of its rocks. We saw the moon's rugged peaks turned into undulating, laminated mounds by the prying cameras of the Apollo missions. But then too, we also found that the moon was not a simple place — examination of the lunar rocks has not led to a clear understanding of our satellite's origin although we do have a much better picture of its structure than we did before.

It is with this sharpened awareness that we scan the moon in the 1970s. Lunar observation requires the least sophisticated optical aid of practically any astronomy endeavor. A 2.4 inch refractor at only 40 or 50 power will reveal all the detail shown in the photograph on page 48. That photo shows the moon at its first quarter phase as it will be on the 20th of this month. On the evenings following that date the moon will be increasingly illuminated by the sun as our satellite pursues its orbit around Earth.

Our last installment in this observing the moon series was in the July 1974 issue. There we were viewing the crescent moon at five days past new; here we see it at the first quarter phase seven or eight days after new moon. The most prominent areas at this phase are the flatlands or so-called "seas". The main ones now in view are Mare Tranquillitatis and Mare Serenetatis. (Unfortunately the Latin names are "official" so we will be using them here.) The first of these was the site of the historic Apollo 11 mission on July 20, 1969. The exact location was not far from the crater Maskelyne. (Craters are named after scientists.)

The vast lunar plains like Mare Tranquillitatis are believed to be gigantic basins that were blasted out of the lunar surface by impacting asteroids back in the early days of the solar system, a few hundred million years after the initial formation of the moon and planets. Rippling across the floor of these two Ohio sized plains are frozen ridges that look like waves of lava that were cooled and became frozen in place. Without going into detail, that is almost exactly what they actually are. The most prominent of these is the Serpentine Ridge which can be easily seen when the terminator (the dividing line between the illuminated and unilluminated portions of the moon) is nearby. The low sun angle makes the floor of Mare Serenetatis look like it is riddled with the underground trails of some monstrous lunar rodent.

The flatlands of the plains provide perfect contrast to the ruggedness of the southern third of our satellite as seen at this phase. On the dividing line between the southern extension of Mare Tranquillitatis and the northern edge of the battered cratered region is the stupendous 67 mile wide Theophilus — one of the truly great spectacles among all the lunar craters. The walls of Theophilus tower more than 21,000 feet above its floor and cast magnificent shadows that intensify its stark rugged appearance. When the moon is about five or six days old the terminator is near Theophilus and the crater is deep in shadow. You may catch it with only its towering central peak rising above the inky blackness giving an eerie and totally unearthly aura to the great crater.

When Theophilus was formed in some unknown era many hundreds of millions of years ago, it smashed down a wall of its nearest neighbor — the equally wide Cyrillus — whose walls are only half as high. Forming a natural third partner is Catherina, also about the same size but in even worse shape with crumbled walls only 9,000 feet higher than its "filled in" floor. These three craters, each in a different stage of decay because of various forces that have affected the lunar surface, provide a cross section of history on our satellite. In general, the steeper the crater and the more rugged its outline, the younger it is considered to be — although young craters may still be well over a billion years old.

South of these three craters is another feature of a different type. Called Altai Scarp, this curving ridge is probably the remains of a vast crater whose center was Mare Nectaris — a smallish plain which, like the others, is really the remains of a large crater. Altai Scarp is undoubtedly one of the walls of that crater although there is not much left of it. At points the scarp is two miles high and is a fascinating feature when the terminator is near it.

Farther south the craters are jumbled together in a way that makes them almost impossible to distinguish until you become very familiar with the lunar countenance. The most prominent of these shoulder-to-shoulder southern craters is Maurolycus, 73 miles wide and 3 miles deep. When near the terminator as seen in our main photo, Maurolycus can be distinguished in rigidly held 7 x 50 binoculars.

Let's now look north of Mare Serenetatis to a small but prominent crater known as Burg. This is one of the steepest walled small craters on the moon. Only 24 miles wide, Burg is 12,000 feet deep. On Earth it would form a fine weather barrier for a city with a population of about half a million. The city could be comfortably nestled inside and have a two mile high encircling mountain.

Closer to the terminator are two supercraters that you just can't miss — Aristoteles is 55 miles wide and 12,000 feet deep, and Eudoxus is 41 miles wide and deeper than its neighbor at 14,500 feet. Because of their location on a nubbly plain, they stand out distinctively along with their smaller neighbor Burg.

The photo and accompanying map on the following pages will lead you to other features of the first quarter moon that your telescope will probably show in more detail than we can illustrate. We've only tried to touch on some of the highlights, but there is certainly far more there than even a lifetime of observing can disclose.

ASTRO-NEWS

Latest News From the World of Astronomy

Solar Model Questioned

The question of what makes the sun shine is probably as old as the human race, but it wasn't until 1938 that a really satisfying answer was given. In that year the basic nuclear processes that occur in the sun's core were worked out by Hans Bethe, who later received the Nobel Prize for his work. His calculations have since been refined and extended, and much of the work has been experimentally verified in accelerator experiments. Ten years ago astronomers were certain that for the first time they had detailed knowledge of what is going on in the solar core. Now they're not so sure.

Most of the energy released by the nuclear reactions in the core of the sun comes off as ultrahigh frequency radiation called gamma rays. It is the descendants of these lethal gamma rays — zigzagging up through the sun, colliding with other particles and losing energy with each collision — that finally, millions of years later, emerge from the sun's surface and reach Earth, stripped of most of their energy and toned down to visible light.

And therein lies the problem. We know that the sun shines because of nuclear reactions that took place in its core millions of years ago. But there is virtually no way of looking directly into the solar core to see if it's still behaving the way it should.

There's that oddball particle — the neutrino — which has no mass and no charge; all it has is energy (and spin, but that doesn't concern us here). When neutrinos are produced in nuclear reactions, they fly off at the speed of light carrying their energy with them, and almost nothing can stop them. Neutrinos produced in the sun's core reach Earth only eight minutes later (the time it takes light to travel from the sun to Earth). If our eyes could see in neutrino "light", we could look right into the core of the sun and observe what was going on there just eight minutes ago.

Failing that, scientists have turned to the possibility of a mechanical "eye" that could detect and analyze neutrinos. Although the odds against a single solar neutrino interacting with anything as it zips through Earth are about 100 billion to one, many trillions pass through Earth every second.

Raymond Davis of the Brookhaven National Laboratory has developed a "neutrino trap" in what has to be the oddest kind of solar telescope yet in existence. In a laboratory located in a South Dakota gold mine a mile underground (to shield it against cosmic rays), he has a 100,000 gallon tank of the cleaning fluid tetrachloroethylene. Scientists originally predicted that about once every three hours a chlorine atom in Davis's tank would be hit in exactly the right way by a solar neutrino with enough energy to knock a negative charge out of its nucleus, transforming it into a radioactive isotope of argon which could be detected by Geiger counters.

Davis's initial results, published in 1968, confounded the astronomers: His upper limit was only one every two days. Theorists protested that his experiment wasn't accurate enough — too many neutrino captures were escaping his detectors. So Davis refined his experiments, and with each refinement his upper limit became less — not more. Today his upper limit is down to about five a month, and the true rate is probably much less.

Theorists are finding it increasingly difficult to construct a viable solar model that squares with Davis's observations. As Roger Ulrich of UCLA

Model *continued on page 53*

Sunspot Pulse Identified

In addition to the 11 year sunspot cycle that astronomers have long known about but never really explained, a mysterious 179 year variation in the sun's temperament has been identified. Completing a new analysis of 214 years of sunspot records, two solar researchers conclude that the 179 year variation results from interaction between the 11 year cycle and a previously unknown shorter cycle of 9.8 years.

The two solar cycles set up a "beat" frequency according to Theodore Cohen and Paul Lintz of Teledyne Geotech in Alexandria, Va. About every 179 years the cycles reach peak activity at the same time, making the sun more energetic than usual. Midway between the long period variation, solar activity falls to lower than normal as both stellar "heartbeats" peak — years apart from each other.

The new finding promises increased accuracy in solar activity prediction — with some very practical benefits. Since the sun's changing electromagnetic mood influences our weather patterns, long-range forecasting could grow more reliable. We may also better anticipate when global communications will be botched up by "noisy" flares and sunspots.

For the next 40 years, the researchers predict sunspot cycles will be calmer than those of previous decades. Coming in 1982, the next solar activity peak should offer only half the activity experienced during the last maximum in 1970. Things won't start picking up again until 2015 when we will be back to the surging activity of the late 1950s. Hopefully by then we'll be receiving global communications via laser or some other sunspot-immune medium.

Scientists View Betelgeuse Surface

The surface of the star Alpha Orionis — Betelgeuse to millions of sky-watchers — appears to be surging, convulsed by massive convection currents according to three astronomers at Kitt Peak National Observatory. Until now, even the world's largest telescopes could only reveal stars as ill-defined light sources — and no instrument has ever been able to discern surface features on any star other than our own sun.

Using a new technique of interferometry analysis, the Kitt Peak team was able to successfully reconstruct Betelgeuse's image. In recording the star the astronomers took photographs using an image intensifier to amplify the image. Short exposure times were utilized to freeze the distortion caused by Earth's atmosphere. These photographs were processed by computer to undo the remaining blur of the image and allow actual images of the star to be recovered.

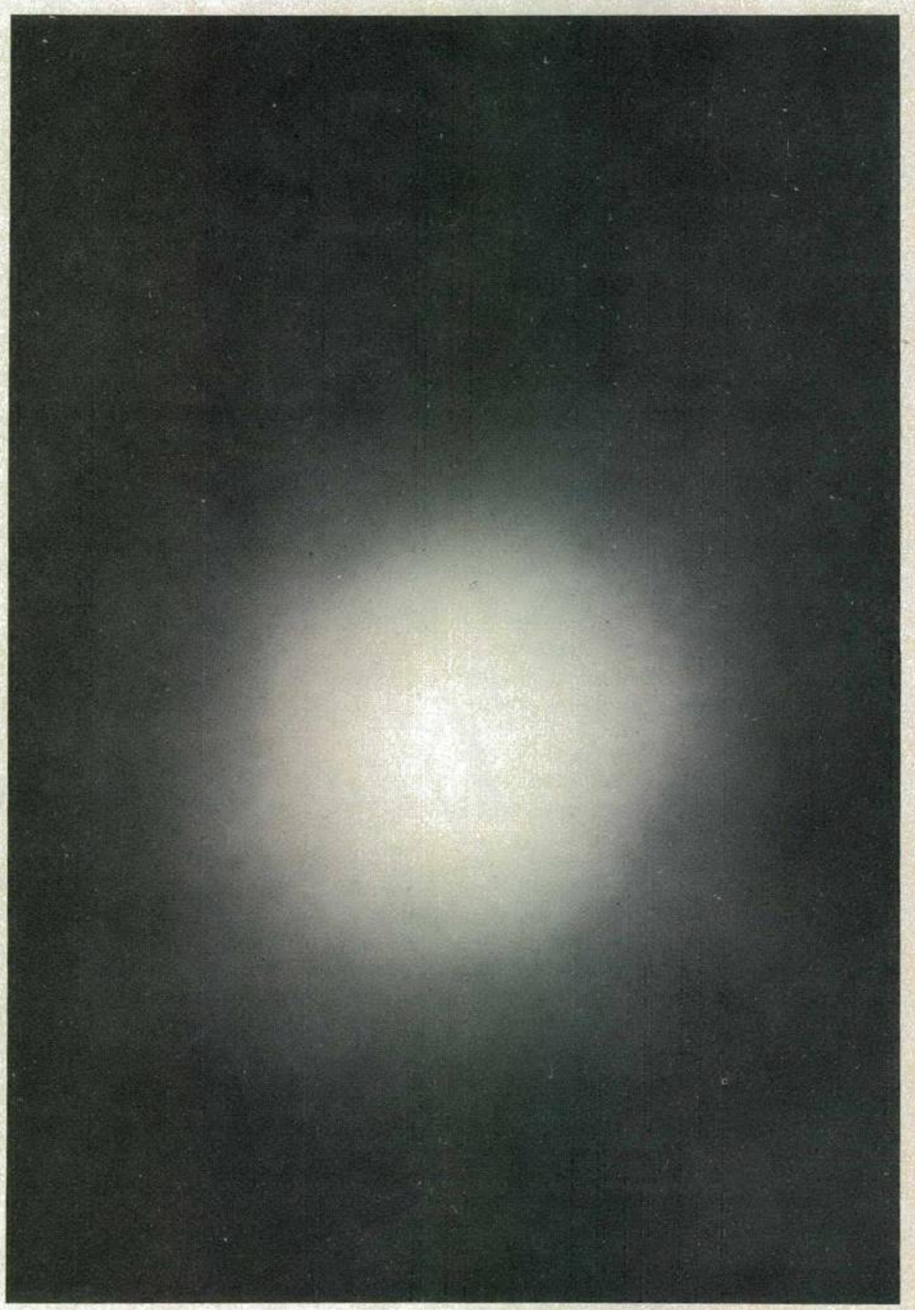
The three astronomers — Roger Lynds, Jack Harvey and Simon Worden — conducted the Betelgeuse photography with the 158 inch telescope atop Kitt Peak. (Along with its recently completed nearly identical twin instrument in Chile, the Kitt Peak telescope is the second largest optical telescope in the world.) Image reconstruction is one of the many new techniques being used by modern astronomers to broaden the reach of existing telescopes.

In resolving the disk of Betelgeuse, the Kitt Peak scientists became the first observers to optically study actual forms on a star other than the sun. The large scale structures seen on the star's surface are thought to be huge regions of hot and cold gases that may be similar to features observed on the sun. The regions are believed to be temperature inhomogeneities showing convection, according to the astronomers.

Betelgeuse was chosen for the study because it is the easiest star to resolve other than the sun. At 500 light-years away Betelgeuse is not a nearby star, but its immense size — 800 times the diameter of the sun — makes it appear larger than any other star when viewed through a large telescope. Even in the most powerful instruments, Betelgeuse's image is seriously distorted by Earth's ever turbulent atmosphere. The new technique has, for the first time, overcome this problem.

Surface convection currents have been predicted by theorists studying Betelgeuse and other red supergiant stars, and the new observations seem to confirm the theories. "The convection cells are huge," says Worden. "One of them can cover five to ten percent of the star's surface." On a star like Betelgeuse that amounts to 200 billion square miles — about 1,000 times the entire surface area of Earth. "One of these cells lasts about six months," he said.

The convection currents are violent enough to eject into space a mass equivalent to several Earths each year. Worden reports that the new observations "are in significant agreement with theoretical concepts of these stars." He said the 158 inch telescopes at Kitt Peak and Cerro Tololo may be used to study Mira and Antares (stars similar to Betelgeuse) to confirm the recent observations.



Kitt Peak National Observatory Photograph

The surface of the red supergiant star Betelgeuse appears in this unprecedented, computer enhanced photograph taken with the 158 inch Mayall telescope. The image measures .05 seconds of arc across, which at Betelgeuse's distance translates to 800 million miles — the diameter of this colossal star. Betelgeuse's granulated texture probably identifies gigantic regions of hot and cool gases.

Lunan's Theory Junked

In 1973, Scottish space enthusiast Duncan Lunan gained international attention with his incredible claim that mysterious, long delayed radio echoes detected in the 1920s were part of a message broadcast by an alien spaceprobe in lunar orbit. Planted in our solar system by a civilization from the star Epsilon Bootes, the probe supposedly called attention to itself by first mimicking any Earthly broadcasts it picked up.

Although scientists have offered natural explanations for these ghostly, long delayed echoes (LDE), none have adequately explained the phenomenon.

Two English radio engineers now suggest that the Lagrangian points (two gravitationally stable regions within the Earth/moon system where a body could remain fixed with respect to both worlds — a kind of Sargasso Sea of space) may sometimes be natural radio reflectors. Tony Lawton and Sidney Newton theorize that interplanetary gas and dust might be temporarily swept into the so-called trailing Lagrangian point that follows along behind the moon in its orbit. Within this region, the particle density could occasionally climb to a point where it resembles Earth's upper ionosphere. Just as the ionosphere bounces some radio frequencies back to Earth, this Lagrangian point may sometimes reflect higher frequencies (normally escaping our planet) Earthward. Bounced along a half million mile path, the radio echoes would have an eerie 2-1/2 second delay.

The British team's analysis of other rare LDE reports shows that the trailing Lagrangian point had luminous patches (indicating a higher than average density) during most of the radio reflections. They claim that chances are 1,480 to 1 against this occurrence being simply coincidence.

Using a donated satellite tracking antenna, Lawton unsuccessfully listened for LDEs of a morse code transmitted by Newton from six miles away. Instead, an Indian radio station (along with a cacophony of other shortwave stations) drowned out Newton's feeble transmission. However, they succeeded in recording a few samples of other radio activity reflected from space.

The British team is confident they have disproved Lunan's theory. "If the probe existed, one would expect it to respond to what was happening," says Lawton. Rather than showing a pattern of intelligent response, the LDEs seem to be completely random. They also argue that if the probe wanted to attract attention it would broadcast on a high frequency wide-band signal that could not be tuned out. Instead, Lunan reported that the supposed artifact returned a low frequency pulsed transmission.

In 1960, radio astronomer Ronald Bracewell first proposed that advanced societies might search for intelligent life by seeding nearby solar systems with robot probes. Inspired by this concept Lunan analyzed a well-known 1928 LDE report and concluded that it represented a coded message describing the location and nature of the probe's builders. Lunan's hypothesis included the alien vehicle at the trailing Lagrangian point — the same zone investigated by Lawton and Newton. The two are not alone in doubting Lunan's theory; other earlier investigators have attacked his report for being as statistically full of holes as a piece of Swiss cheese.

Model

continued from page 51

wrote in a recent article in the **Astrophysical Journal**, "There are just two ways that a count rate less than (one neutrino capture every 12 days) could be reconciled with the idea that nuclear reactions are responsible for the solar energy. These are (1) the neutrinos decay in transit to Earth, and (2) the sun is in a transient phase."

There is no observational evidence whatever to support the rather farfetched hypothesis of neutrino decay, and the idea is contrary to established physics. Nevertheless, so little is known about neutrinos that scientists cannot dismiss it out of hand. But assuming that established physics is right and that neutrinos do not decay, we are left with the second alternative: The sun is in a transient phase — in other words, the sun is "turned off".

Astronomers hasten to say that this "transient phase" cannot last for more than a few hundred thousand years, after which the sun will readjust itself and turn on again. But they have no way of knowing how long this transient phase has been going on. Ten years? Or a hundred thousand years? Is some effect bound to reach the solar system in the immediate future? Will the life-giving energy now radiated from the sun dwindle alarmingly? Astronomers pooh-pooh the idea. But the discovery that the nuclear fires in the sun's core may be banked is so new that the full ramifications have not yet been worked out. Meanwhile, it remains an exciting — and vital — field of astronomical research.

NASA to Fly Experiments On Soviet Craft

In a historic gesture of cooperation, the USSR recently invited NASA to place experiments on board a Soviet biological satellite scheduled for launch later this year. The offer, made during the joint session of the US/USSR Working Group on Space Biology and Medicine, also welcomed American scientists to participate in pre- and postflight research on Soviet blood and tissue experiments scheduled to be flown on the upcoming mission.

NASA scientists are now busily selecting experiments for the flight and are submitting plans to the USSR. David Winter, NASA director of life sciences, says that experiments being considered include fish embryo development and plant and tissue studies. One United States experiment could be placed in a Soviet centrifuge housed on board the spacecraft for generating artificial gravity.

Without this free ticket from the Soviets, U.S. biological space experiments would have remained at a standstill until the 1980 completion of the Space Shuttle. (The last experiments were flown aboard Skylab.)

The Russian series of biosatellite space missions began in 1973 with the flight of Cosmos 605. Failure of the life support systems ended the 605 mission prematurely, forcing a repeat flight in late 1974. Both flights were scheduled to last three weeks, and carried a variety of small laboratory animals.

The Soviets are keeping the red carpet out for U.S. involvement in future biosatellite missions. Next year NASA will discuss additional experiments including such areas as gravity effects, bone and tissue dematerialization, weightless influences on the inner ear, and cosmic ray effects.

Space enthusiasts hope that such international efforts as the biosatellite program and the upcoming manned Apollo/Soyuz orbital rendezvous will lead the U.S. and USSR into jointly undertaking major lunar and planetary exploration projects — endeavors that would otherwise be an unpopular burden on a single nation's economy. Such a spirit of cooperation would help put space exploration in its proper perspective — as a venture to be shared by all mankind.

Strange Signals May Be Black Hole

Monstrous surges of gamma ray radiation from deep space continue to baffle astronomers after over a year of investigation. One of the many theories being offered suggests that we are detecting the "death throes" of matter plunging into black holes — those gravity whirlpools from which nothing can escape.

The only known example of a black hole is Cygnus X-1 (so-called because vast quantities of X-rays have been detected streaming away from it). Since both X-rays and gamma rays cannot penetrate Earth's atmosphere, only satellites can measure them.

As often occurs in science, the gamma ray events were detected by an experiment designed for another purpose. It happens that the detonation of a nuclear weapon also releases a burst of gamma rays. To ensure no such detonations go undetected, the United States has launched a series of gamma ray monitors into orbit around Earth. It is these military satellites — known as Vela vehicles — that detected the cosmic gamma ray surges.

A particularly violent burst was recorded on March 15, 1972 — about the time Cygnus X-1 became an "energetic" X-ray object. "The correlation suggests something happened to the Cygnus X-1 black hole," says Ian B. Strong, a scientist at the Los Alamos Scientific Laboratory in New Mexico who is involved with the interpretation of signals returned from the Vela detectors.

Strong and other scientists are perplexed by the nature of the signals. "The signals seem to come in at random with a slight indication that they are coming from within our own galaxy," says Strong.

The evidence that the source is within the Milky Way galaxy is not conclusive but it does support the concept that black holes are somehow responsible for the bursts of gamma rays. The Cygnus X-1 black hole is about 6,000 light-years away — well within our galaxy.

The observed bursts are equivalent in energy to the simultaneous detonation of hundreds of billions of hydrogen bombs — far more powerful a release of energy than the normal output of our sun.

Other theories attempting to account for the gamma ray bursts include such bizarre events as volcanos on neutron stars. (A neutron star is the compressed remains of an exploded star.) Still other theories evoke comets crashing into neutron stars or enormous flares from otherwise near normal stars.

It seems like the astronomers are tossing out any idea that might explain the signals. Such "arm waving" is a sign that a truly perplexing problem has emerged. The only suggestion not made is that the gamma ray bursts are due to the activities of some extraterrestrial civilization. The random nature of the signals seems to rule that out.

Universe Without End

Kitt Peak National Observatory Photograph

Appearing deceptively static, this recently photographed unnamed cluster of galaxies is among myriad other galaxy clusters that are all racing away from hundreds to tens of thousands of miles per second. Cosmologists are anxiously trying to determine if this sobering image of a universe flying apart like an exploding firecracker means that the expansion will continue forever. If so, then someday in the distant future all galaxies — including these — will vanish into infinity.

Model Suggests Solid Martian Core

Missing from the bag of surprises about Mars given us by recent space probes like Mariner 9 is evidence ending scientific debate over whether the red planet has a liquid core (like Earth's) or a solid one. The existence of a weak magnetic field around Mars (which could imply a liquid core) is still uncertain, and pictures of volcanos, domes and craters don't really tell us about the planet's present temperature.

Now a new thermal model of the Martian interior by Richard Young and Gerald Schubert of NASA's Ames Research Center suggests that Mars contains a cold, solid core.

Like Earth, the Martian model is divided into a core (iron or iron sulfur in this model) surrounded by the so-called mantle, which in turn is wrapped in the hard shell of an outer crust. Also like Earth, Mars' mantle probably carries heat away from the core to the outer crust by convection currents.

In convection currents, mantle material heated by the core rises — much like hot air — to the crust where it cools and sinks back toward the planet's center, beginning the cycle again.

The two researchers calculate that Mars' mantle should flow quickly enough to do an efficient job of cooling down its core — so efficient that it likely keeps the core temperature below the point where iron turns to liquid.

Their thermal model also implies that Mars has a tougher hide than Earth. As opposed to Earth's thin, 30-mile deep crust, Mars' crust sinks a few hundred miles into the planet.

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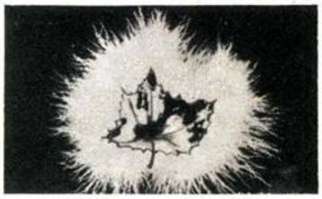

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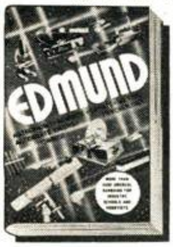

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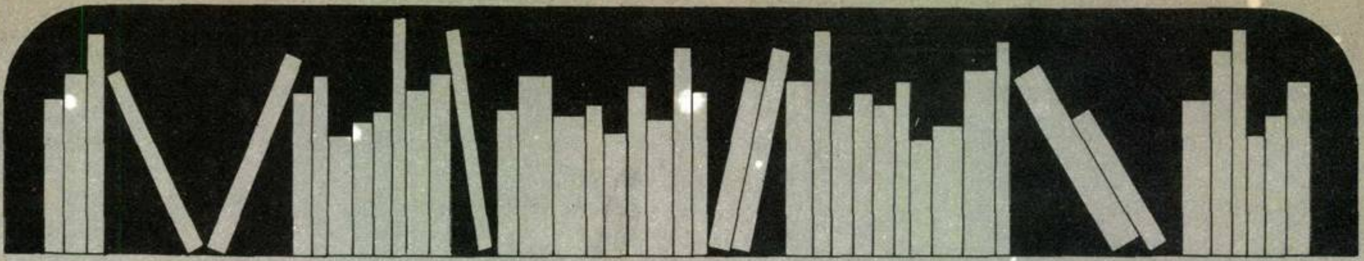

ASTRONOMY REVIEWS

1975 Yearbook of Astronomy

edited by PATRICK MOORE

221 pages, hardcover, $8.95
W.W. Norton and Company (1975)

It's always enjoyable to be able to look forward to some exciting astronomical event in the coming months. That's the purpose of an annual celestial calendar — detailing the predictable sky phenomena for the coming year. This publication does not succeed in fulfilling this primary aim. Only about 1/ 3 of its pages are applied to descriptions of celestial events for 1975. The remainder are devoted to articles ranging from the mysteries of quasar redshifts to the problems of school astronomy.

The articles vary in length from just a few lines to a 20 page treatment of the decameter-wave radio astronomy of Jupiter. The editor and most of the contributors are British amateur or professional astronomers. Thus in certain instances, material written for the British reader will be of little interest to readers here in the United States.

Observers will also be disappointed in some of the charts in the **1975 Yearbook of Astronomy**. The chart for Vesta, for example, shows no sixth magnitude stars and yet Vesta itself is no brighter than magnitude 6.2 in 1975 — so the observer is unable to distinguish Vesta from among the sixth magnitude stars in its vicinity using this chart. The same thing holds true for the Uranus and Neptune charts.

Although there are some interesting articles in this publication such as detailed discussion on planetary nebulae and an interesting historical footnote on Heinrich D'Arrest and the discovery of Neptune, the **1975 Yearbook of Astronomy** cannot be recommended when superior publications such as the **Observer's Handbook** of the Royal Astronomical Society of Canada or the **Astronomical Calendar 1975** (both reviewed last month) are available at much lower cost.

The reader will find this book a relatively minor reference tool after the articles have been read. In this respect it's more like an issue of a journal than an almanac type publication.

* * *

The Viking Mission to Mars

by WILLIAM R. CORLISS

77 pages, paperback, $1.20*
U.S. Government Printing Office (1974)

Mars has fascinated mankind for thousands of years. From the god of war to the home of the mysterious canals, the red planet has been an object of worship, curiosity and fear. Although knowledge of the real conditions on Mars has been expanded tremendously in the past 10 years, the fascination with the planet has not decreased but has grown more intense. Perhaps the on-again off-again speculation about life on Mars will soon be answered.

In 1976 (with the standard proviso "if all goes well"), two American probes will land on Mars and begin a search for living microorganisms. The discovery of life beyond Earth will have stunning implications for biology, cosmology, theology, and other disciplines. The only question seems to be where and when it will be discovered.

This comprehensive NASA booklet describes the history of Mars exploration since the first spacecraft reached the planet in 1965. But the main topic of the book is Viking.

Details are presented in a clear, readable style with many diagrams and photographs. The mission is outlined, and the spacecraft and rocket are described. The experiments — on route, in orbit, during atmospheric entry, and ultimately on the surface — are all extensively treated. A complete picture of one of the most exciting space missions of the decade is the end result. Readers will want to have this guidebook on hand as the Viking missions progress.

** Stock number 3300-00561; for sale by Superintendent of Documents, Washington, D.C. 20402.*

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Pictorial Astronomy

by D. ALTER, C.H. CLEMINSHAW and J.G. PHILLIPS

328 pages, hardcover, $12.50
Thomas Y. Crowell Company (1974)

"The past few years have witnessed an almost explosive series of advances in astronomy that have revolutionized and expanded most dramatically our concept of the physical universe."

This profound but undeniably true statement opens the fourth revised edition of one of the most successful astronomy books of the 20th century. There is no doubt why **Pictorial Astronomy** has achieved prominence since it was first published in 1948. Select any chapter and you will be unable to put the book down. It's a delight to skip from one area of interest to another — perhaps from a section on great comets of the past to the Magellanic clouds to life in the universe.

On almost every page is either a photograph or diagram to illustrate the chapter's subject matter. Although there are no color illustrations at all, the quantity and quality of the black and white photographs is outstanding — perhaps unrivaled by any other general astronomy book.

Other features include the chapter "How to Recognize the Stars", which contains excellent finder charts and a pronunciation list for the constallations and brighter stars.

One thing that this book is not is one of those phony revised editions — where a new dust jacket is put on, a few new photos are slipped in somewhere, or even a new chapter is added at the beginning or end of the book. The revised edition of **Pictorial Astronomy** is truly that — it's like a new book. The text has been changed wherever necessary; old photographs have been removed and newer ones inserted.

But most of all it's the writing that makes this such a useful book. It's easy to read, yet informative; light, but loaded with facts. The happy combination will make this one of the most valuable additions to your library.

* * *

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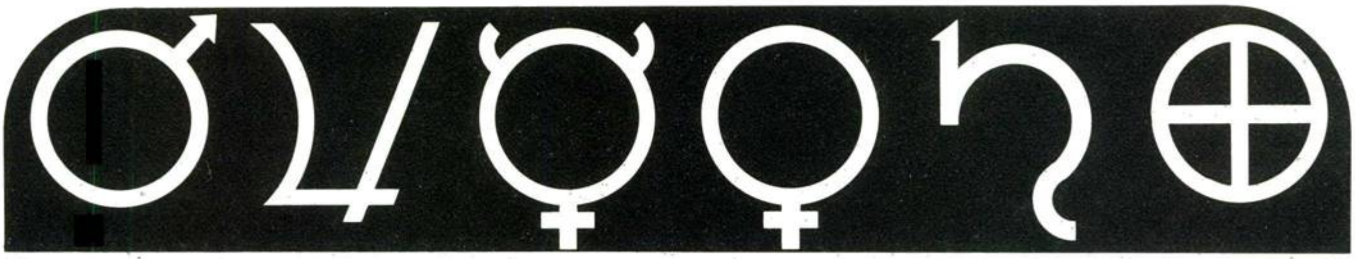


SKY ALMANAC

March Springs Temperate Skies

Changes in both Earth and the sky mark the dominant pattern in March — observing conditions improve along with the weather as the month progresses, while in the sky the changes are rapid and noticeable. Jupiter is gone but is replaced by Venus in the west, and Saturn now hangs high in the evening sky continuing a perfect observing position that began late last year.

Saturn

With Pioneer 11 now definitely on its way to the solar system's most uniquely adorned planet, we can anticipate some of Saturn's secrets yielding to the cold electronic eyes of space robots. But that won't be until 1979 — and this year the telescope still reigns supreme as the only way to get a close-up view of the ringed planet.

Any telescope will do for Saturn exploration — a small refractor with a two inch objective lens magnifying 30 times should clearly show the rings. The view improves along with increased telescope size — but if you are operating with a small telescope don't despair; that 30 power two incher should also show Titan, Saturn's largest moon. Titan is now the subject of intense scientific scrutiny as Carl Sagan describes in the lead article this month. You can identify Titan by using the information in the table on page 60. That table also lists the elongations of the other Saturn moons that are visible in larger instruments. (Check the January 1975 issue for more tips on observing Saturn and its moons.)

For nontelescope users, Saturn can be found nearly overhead in the early evening sky — far out-shining Castor and Pollux, the brightest stars in the constellation Gemini where the planet now appears. Saturn takes 30 years for a complete trip around the sun and consequently takes that long to appear to us to move around the sky. Its two year visit to Gemini will be over this year and in 1976 it will move to the dim constellation Cancer next door to Gemini.

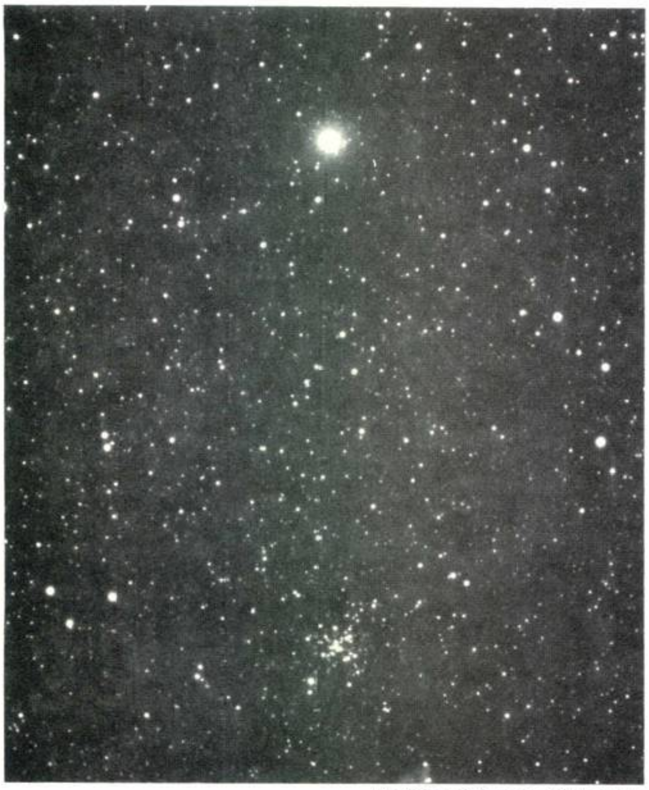
Try comparing Saturn to Betelgeuse or Rigel in Orion, or Capella in Auriga. It should seem slightly brighter than Betelgeuse but virtually indistinguishable from Capella and Rigel. The differing colors of these three stars will make the comparisons difficult. Some people see red stars brighter than their listed magnitudes, while to some the blue stars seem brighter.

Saturn's true apparent magnitude drops from +0.1 to +0.3 during the month as it increases its distance from Earth from 788 million miles to 832 million. This increase in distance causes a corresponding decrease in the apparent size of Saturn as seen through a telescope. Its width from ring-tip to ring-tip diminishes from 44.3 seconds of arc on the 1st to 41.9 seconds of arc by the 31st. The disk of Saturn itself is about 19 seconds of arc in diameter at this time.

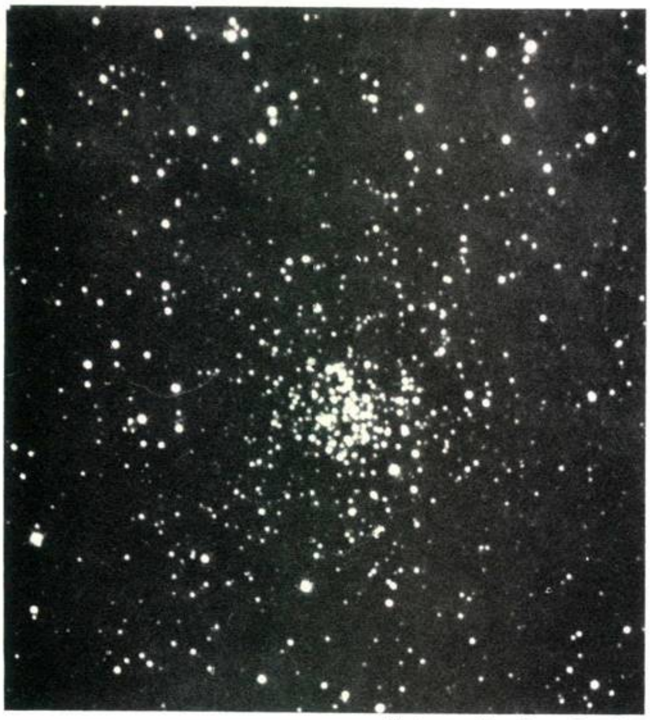
Although Saturn is somewhat farther away and slightly smaller than it was earlier this year, conditions are still excellent for telescopic study. Is your telescope capable of showing the kind of detail that appeared in the cover photograph of the January 1975 issue? How many satellites of Saturn do you see with your telescope? These little observing

One side of 7 x 50 binoculars was used as a makeshift telephoto lens for this partial eclipse photo taken from West Palm Beach, Fla. High Speed Ektachrome (indoor type) film was used while fully exposed and developed Kodak Tri-X film acted as a filter in front of the binoculars.

Photograph by Norman F. Lewis



Photograph by Leo C. Henzl Jr.



Photograph by Dana Patchick

Three winter objects — one famous and two less well-known — are captured here in two "piggyback" guided photos. Above is Sirius, the brightest star in the night sky, with the star cluster M-41 nestled four degrees to the south. This 12 minute portrait through a 135mm Canon f/2.5 lens was taken on Fujichrome R-100 color film. Centering your telescope on Sirius, it should be easy to find M-41 using this photo as a celestial road map. (Both M-41 and Sirius are described in this month's Star Dome.) Below is the open cluster of several hundred stars known as M-67. Located in the constellation Cancer (see map, page 70), it is seen here much as it appears in a moderate sized telescope. At an overall magnitude of seven — one magnitude fainter than M-41 — this cluster is less impressive than its counterpart in Canis Major. A four inch f/5 reflector was used for this 17 minute exposure on Kodak 103aF film; the photo width is 1.5 degrees.

OBSERVING SATURN'S SATELLITES

Date	Time	Satellite	Direction
March 2	7:30 p.m.	Tethys	E
3	1:30 a.m.	Titan	E
5	2:15 a.m.	Dione	E
6	9:00 p.m.	Rhea	E
8	8:00 p.m.	Dione	E
10	7:00 p.m.	Titan	W
11	6:00 a.m.	Tethys	E
13	3:15 a.m.	Tethys	E
15	12:30 a.m.	Tethys	E
15	11:00 p.m.	Rhea	E
16	1:00 a.m.	Dione	E
16	10:00 p.m.	Tethys	E
18	12:00 p.m.	Titan	E
18	6:45 p.m.	Dione	E
18	7:00 p.m.	Tethys	E
24	6:45 p.m.	Rhea	E
26	6:00 p.m.	Titan	W
26	11:45 p.m.	Dione	E
28	5:45 a.m.	Tethys	E
29	10:30 p.m.	Dione	E

This table provides all the necessary information for identification of Saturn's satellites Titan, Rhea, Tethys, Dione and Iapetus. E or W refer to extreme east or west points of the satellites' orbits. For Tethys and Dione, only eastern elongations occurring during darkness in the United States are included. Use this table in conjunction with the illustration on page 52 of the January 1975 issue.

challenges add to the truly splendid appearance of this jewel of the solar system.

Venus

Telephones at planetariums and observatories around the country are ringing again as the unidentified flying object reports come in from non-astronomy types who don't recognize Venus for what it is — namely, the brightest object in the sky apart from the sun and the moon. Because of its favorable position right now it can be seen low in the west in a totally black sky a little over an hour after sunset.

At magnitude -3.4 this month, Venus is 28 times brighter than Saturn and six times brighter than Sirius, the brightest true star in the nighttime sky. When Venus gets carried close to the horizon by Earth's rotation, its normally steady white light is subjected to the massive distortions and turbulence of our atmosphere. The turbulence is especially heavy because we're looking through the

The open cluster M-46 contains over 100 stars of ninth magnitude and fainter. A faint version of the Ring nebula appears to be within this stellar assemblage — however it is believed to be unassociated with M-46. At the center of the cluster the stars are barely more than one light-year apart. (For more details see page 75.) Cooled emulsion High Speed Ektachrome film was used for this photo through a 12 inch Newtonian reflector; photo width is about one degree.

Photograph by Evered Kreimer

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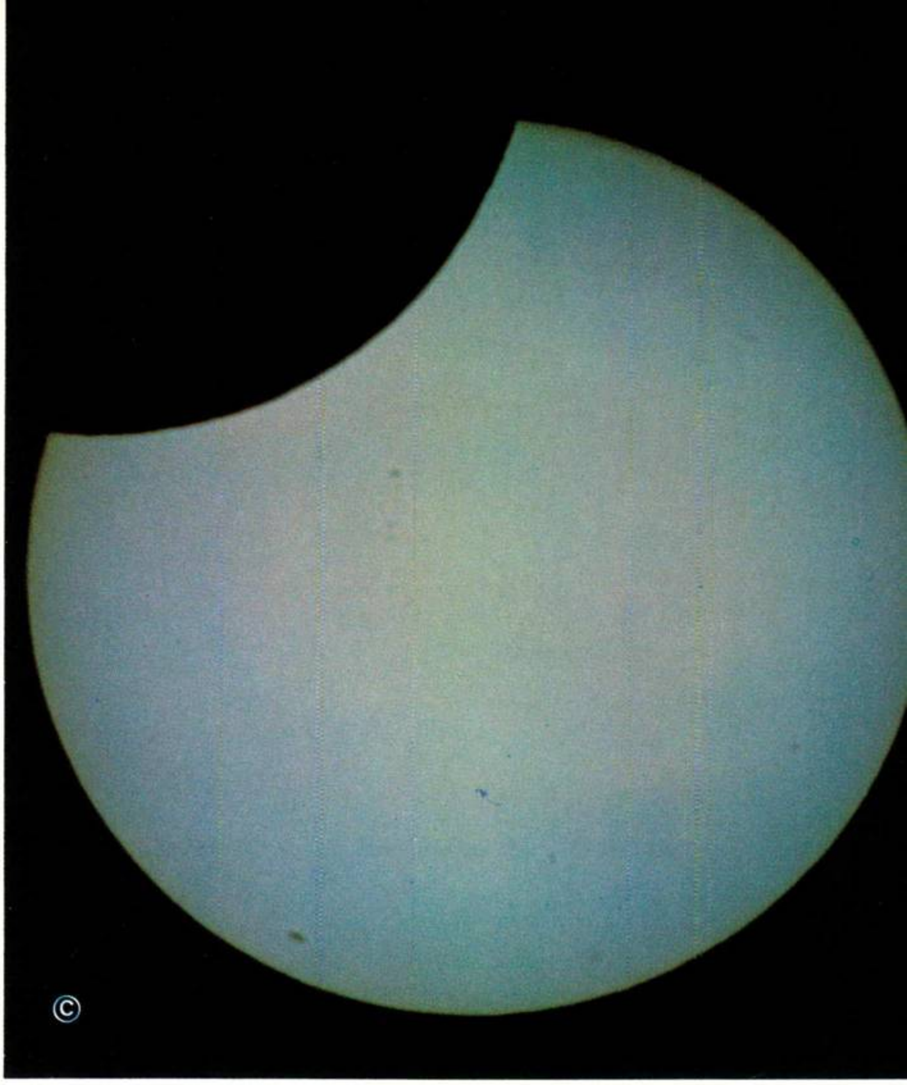
Ⓑ



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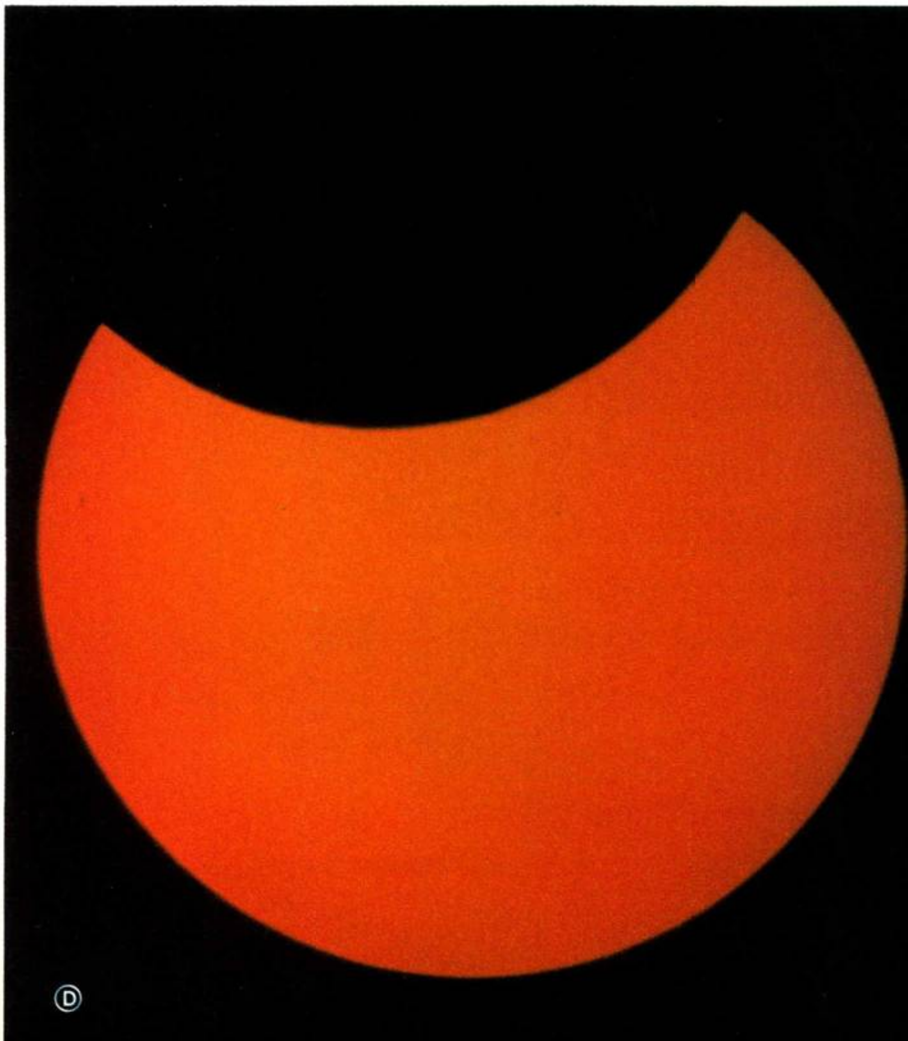

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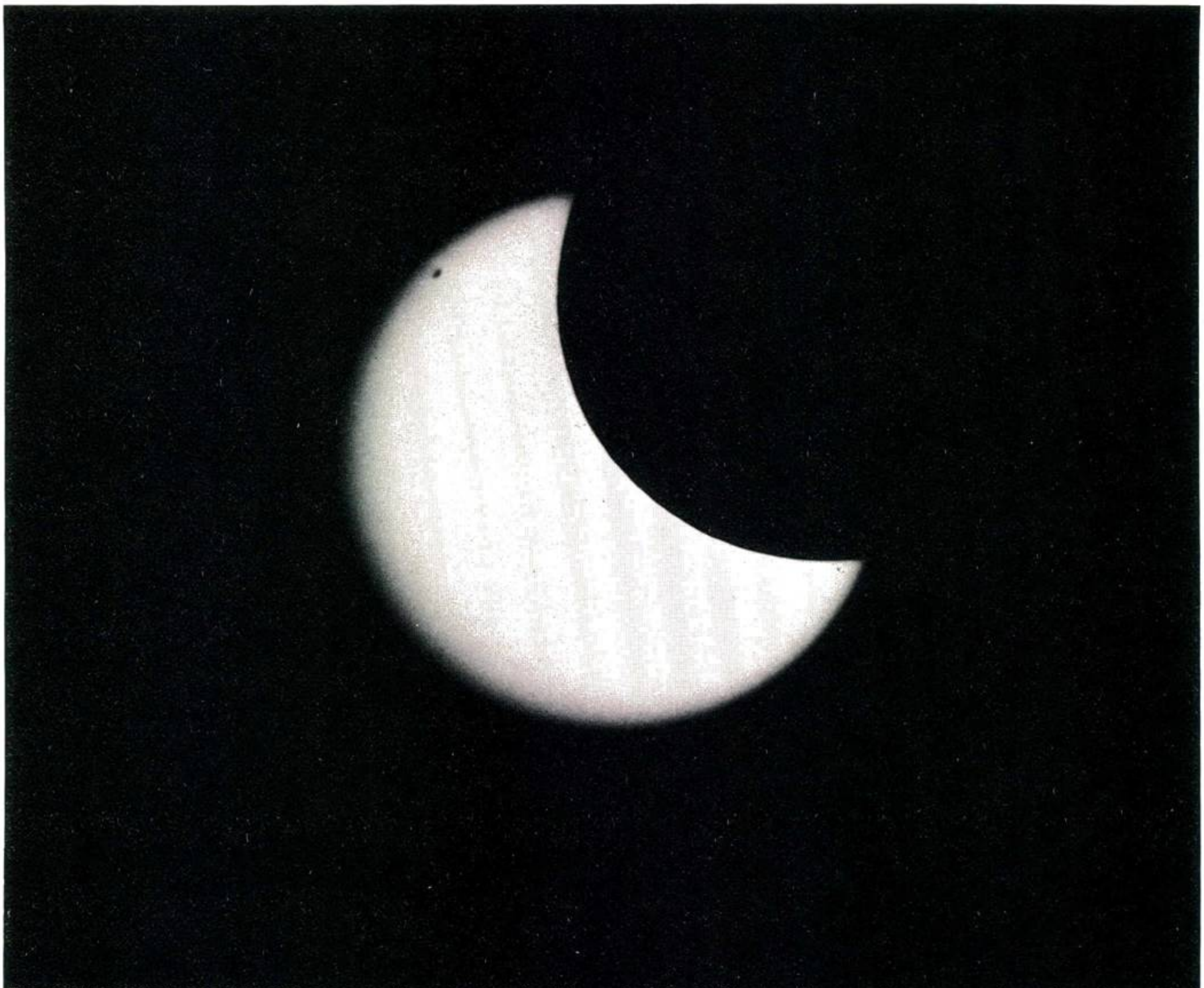


Excellent contrast, unobtainable on color films, is seen in this Solar-Skreen filtered image of the partial eclipse of Dec. 13, 1974. The amount of sun obscured in this 1/30 second exposure is typical of the maximum eclipse as seen from the midwest and south. The photo on High Contrast Copy film was taken through a 2.4 inch refractor.

Photograph by David W. Hudgins

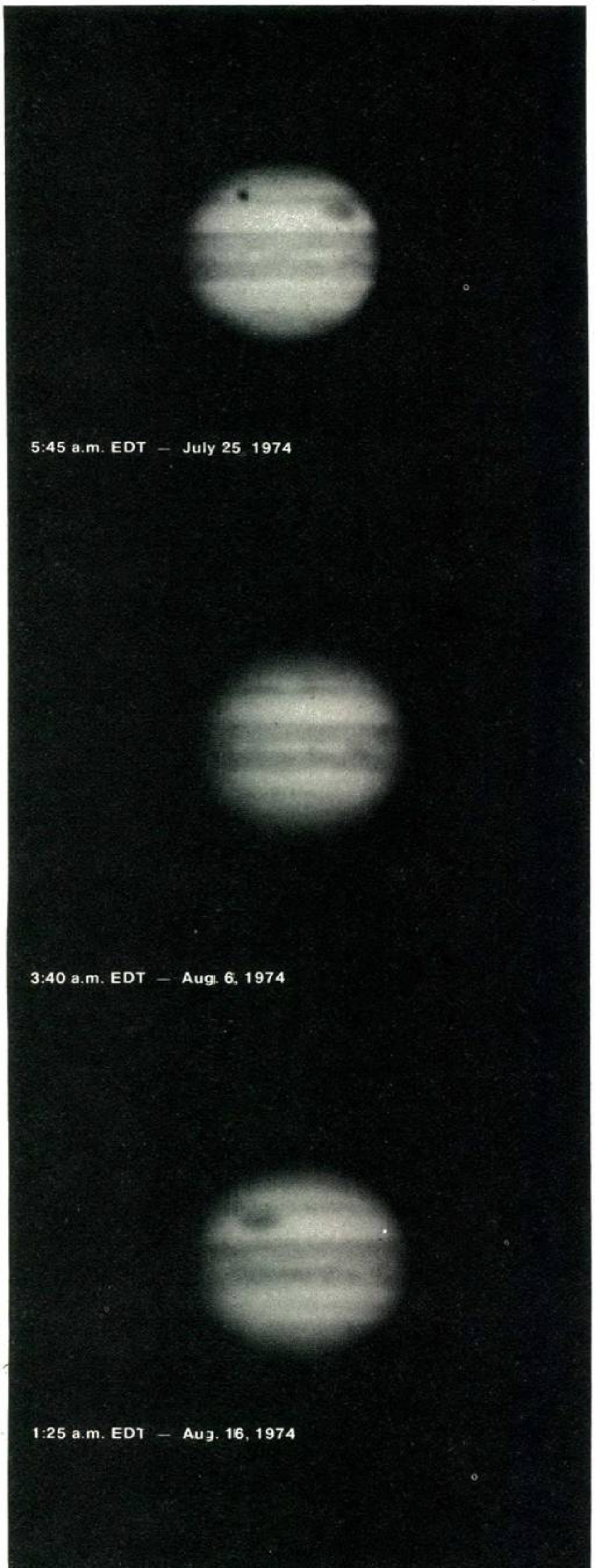
(A) Sunrise at Winnipeg, Canada was unusual on Dec. 13, 1974. A neat "bite" taken out of the sun's upper edge could be easily seen through the thin clouds that veiled the horizon. This unfiltered partial eclipse photo was taken on High Speed Ektachrome with a 135mm lens. (B) The odds against seeing a jet cross the face of the partially eclipsed sun must be "astronomical". Observing from Manhattan, Kans., our two photographers were "sitting in the car keeping warm when we noticed a jet going over. We ran to the telescope just in time to shoot this picture." The telescope was a Celestron 8 equipped with Celestron's full aperture filter. The 1/1000 second exposure on Kodacolor II film was taken with a Nikon F2 camera body at the telescope's prime focus. (C) The partial eclipse was in progress when this 1/60 second exposure was taken through a 12-1/2 inch Newtonian telescope at Norman, Okla. A Solar-Skreen full aperture filter brought the prime focus image to an intensity level that could be conveniently exposed on the Kodachrome 64 film. Solar-Skreen imparts a bluish cast to the image unlike more expensive full aperture filtration systems used for photos displayed on these pages. (D) Smaller apertures can be employed for good results in solar photography. Here a six inch f/4 Newtonian reflector was stopped down to 2.4 inches by an off-axis solar filter. A Barlow lens increased the image size so that it nearly fills the Ektachrome-X 35mm frame. The photo was taken from Naples, Fla.

(A) Photograph by Phyllis Belfield (B) Photograph by Wayne McGill and Mike Sankey (C) Photograph by Mike Pierce (D) Photograph by James Rouse.

greatest thickness of air as we skim the surface of Earth gazing toward the horizon.

Although the image of Venus may look stunning as it flashes and changes color like a beacon above the horizon, this is the worst time to view it with a telescope. Try to catch Venus as soon as you can after sunset. On clear evenings it should be easy to spot only 10 or 15 minutes after sundown. A telescope turned to the planet at such times this month will show a gibbous (3/4 illuminated) disk, somewhat smaller than the ball of Saturn appears in the same telescope at the same magnification.

Venus is now moving toward us, decreasing its distance from 134 million miles at the beginning of March to 119 million miles at month's end. Although the diameter of Venus grows from 11.6 seconds of arc to 13.1 seconds during that period, we see less of its illuminated face so its magnitude stays about the same. The actual change in phase is from 89 percent illuminated to 82 percent. Next month Gazer's Gazette will be devoted to detailed discussion of Venus and its observation.



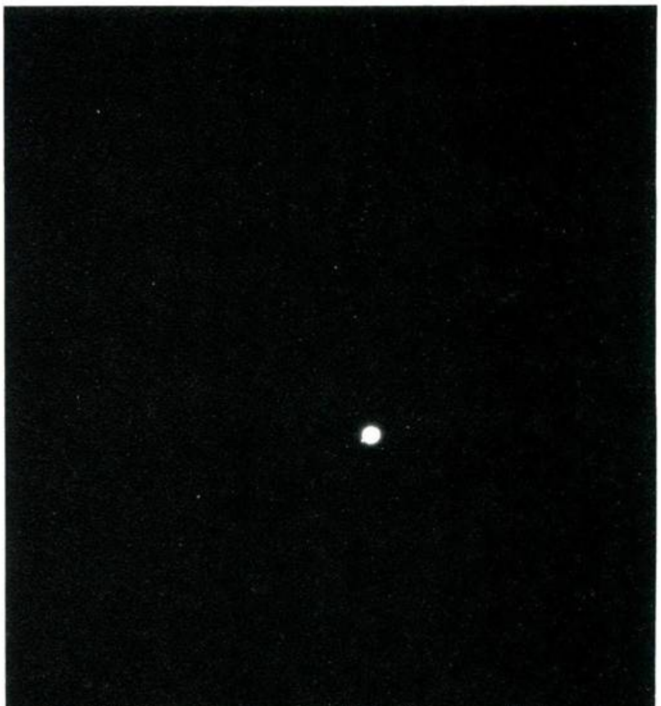
5:45 a.m. EDT — July 25 1974

3:40 a.m. EDT — Aug. 6, 1974

1:25 a.m. EDT — Aug. 16, 1974

Jupiter is no longer in the evening sky but these photos provide a record of its appearance last summer. Callisto's shadow joins the Great Red Spot in the upper photo. All three of these 12 inch telescope photos are one to two second exposures on Kodak SO-410 film developed in ethol blue. The same combination was used for the one second exposure (center).

Photograph by John Sanford



Dec. 7, 1974 was the evening of the "disappearing" moons of Jupiter as explained in this department in the December 1974 issue. The 12 second prime focus photo through a Celestron 8 inch shows Callisto at far left with Europa and Io flanking Jupiter immediately to the left and right of the disk. The High Speed Ektachrome film is reproduced here in black and white.

Photograph by Roy Belfield

Mercury

The inner planet makes a brief appearance in the east before sunrise this month. But it is so low and will be so difficult to observe that astronomy enthusiasts will be wise to wait until the very favorable conditions in May to conduct their Mercury observing.

Mars

Mars, like Mercury, can be seen very low in the east before sunrise but it will be in much better position later this year.

Uranus, Neptune, Pluto

The three outer planets are soon going to be in convenient positions in the evening sky; maps for locating each of them will appear in future issues. On the 29th, Pluto will be nearest Earth at a distance of 2.77 billion miles.

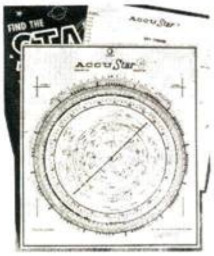
Spring Begins

If local weather patterns paid any attention, the exact moment of the beginning of spring would be significant — but it isn't. For those who are interested, the official moment is 1:57 a.m. EDT Friday, March 21. The sun is then on the celestial equator and the length of day becomes longer than night for the first time in six months.

Planet Finder

Last month the planet finder chart was shifted to the back of the magazine (pages 76 and 77) where it will remain for the next few issues.

easily locate any celestial object



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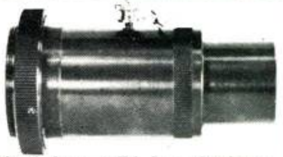

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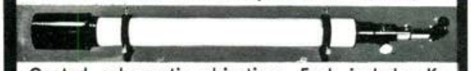

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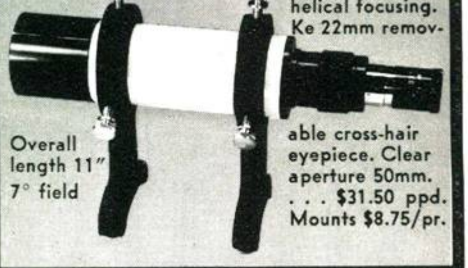

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MARCH

Just as March signals a change from cold winter days to promises of spring, March skies also appear in transition as constellations of two seasons share our Star Dome. The winter family of constellations inhabits the western sky while spring constellations rise in the east, challenging the winter group's domain. But in contrast to winter's shimmering sky show, spring star patterns seem pretty stingy in the number of bright stars they possess.

Orion the hunter remains the month's most splendid and best recognized star dweller. Four brilliant first and second magnitude stars frame his famous belt, an almost perfectly straight row of three equally spaced stars. Orion is frozen into a confrontation with the angry bull, Taurus, adding some excitement to an otherwise peaceful winter family. His belt points up toward the bull which is charging from the right.

Taurus glitters with two of the sky's most spectacular star clusters — the V-shaped Hyades outlining the bull's face, and the Pleiades, a smaller cluster of seven visible stars locating Taurus' shoulder. Two ominously long horns extend from the top of the V.

The right horn points at Auriga the charioteer, a pentagon shaped constellation marked by +0.1 magnitude Capella. Because of its beckoning brilliance, Capella was worshipped in the Egyptian temple of Karnak and honored in India as the heart of the Hindu god Brahma.

The left horn threatens Gemini the twins, a roughly rectangular shaped constellation capped by the stars Pollux and Castor. Both Gemini and Taurus are among the zodiacal constellation roadsigns marking the highway that the sun and planets travel across the starry background. Glistening Saturn now crawls through the center of Gemini's rectangle at what seems a snail's pace — at least by Earthly standards.

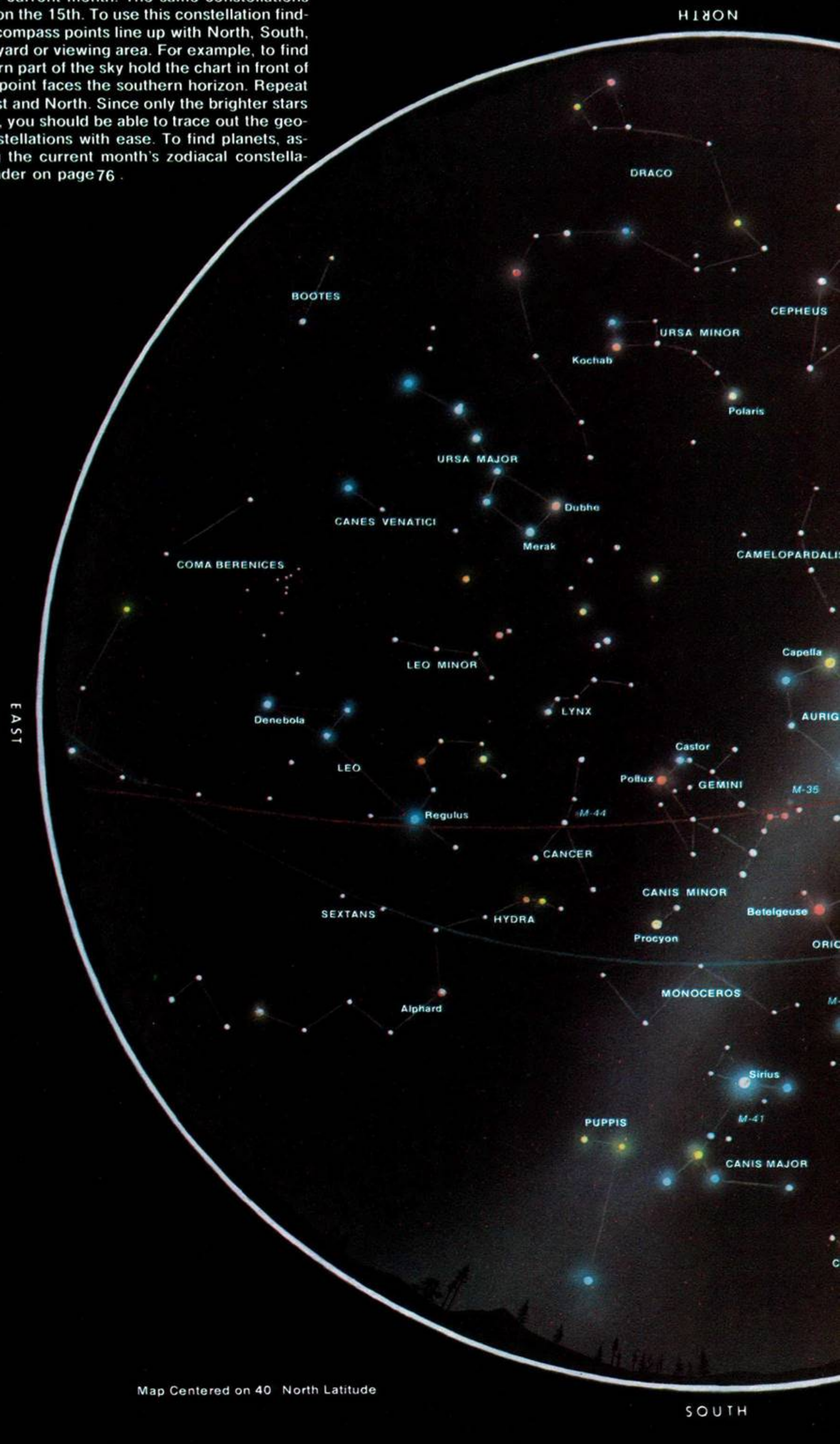
In about a year Saturn will enter the dimmest of all 12 zodiacal constellations — Cancer the crab. A Y-shaped pattern of stars no brighter than fourth magnitude is all that indicates the crab. One easy way of finding the constellation involves drawing an imaginary line from Capella through Castor (the right member of the Gemini star pair).

In ancient times the sun was located in Cancer during the summer solstice (when the sun reaches its northernmost point above the equator). On the mornings preceding the first day of summer (June 21), our sun appears to rise increasingly farther northeast. After the 21st it abruptly changes direction, coming up ever closer to due east and eventually southeast. This annual back and forth motion reminded ancient astronomers of a crab crawling sideways, and inspired them to name this region of the sky in honor of the crustacean.

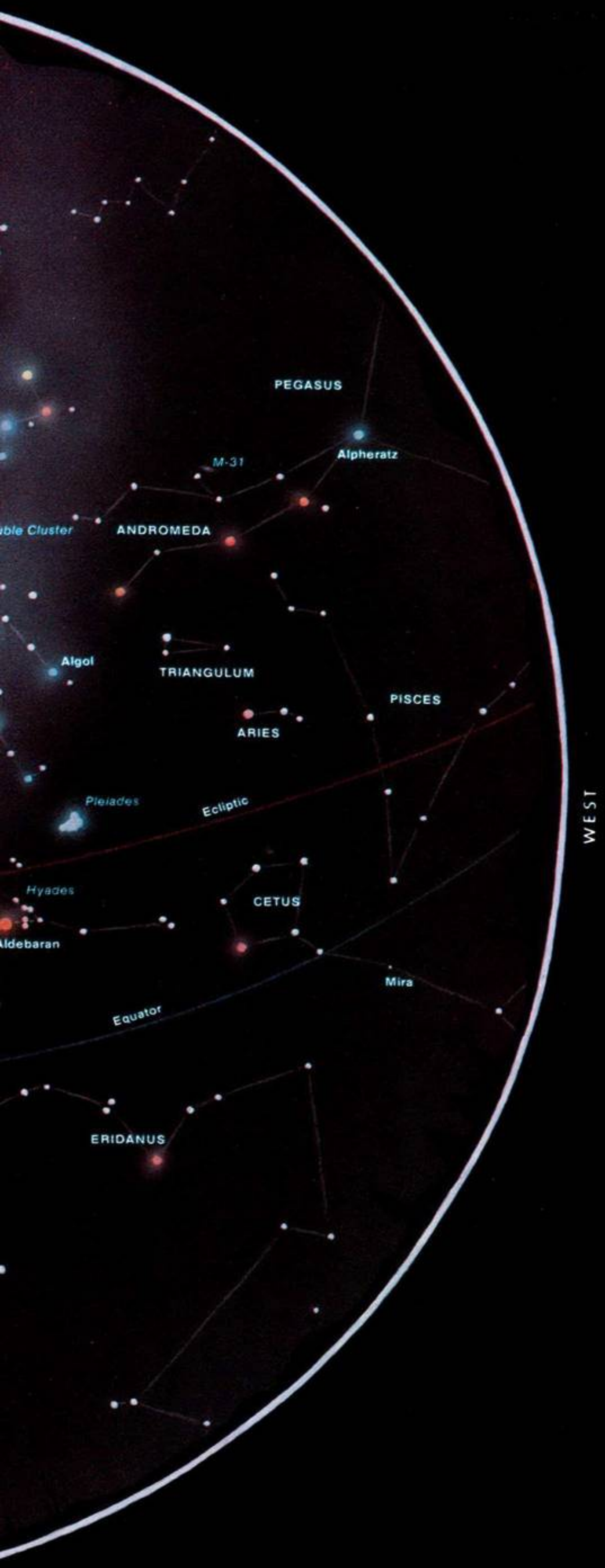
Cancer plays a sinister role in mythology. Jealous of Hercules (son of Zeus resulting from one of his amorous adventures with Earthly women), Zeus' wife Hera sought to punish the young warrior by sending a giant crab to attack him during his deadly struggle with Hydra the water serpent. Mighty Hercules, strongest of all Greek heroes, easily crushed the annoying crab. To reward the poor beast for its bravery, Hera transformed Cancer into a constellation.

On moonless nights the star cluster M-44, commonly called the Beehive, is visible inside a small square of stars within Cancer. For naked eye

Star Dome approximates the sky as it appears at 8 p.m. Local Standard Time on the first day of the current month. The same constellations are visible one hour earlier on the 15th. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 76.


NORTH
DRACO
BOOTES
CEPHEUS
URSA MINOR
Kochab
Polaris
URSA MAJOR
Dubhe
CANES VENATICI
Merak
COMA BERENICES
CAMELOPARDALIS
LEO MINOR
Capella
EAST
LYNX
Denebola
AURIG
Castor
LEO
Pollux
GEMINI
M-35
Regulus
M-44
CANCER
CANIS MINOR
SEXTANS
HYDRA
Betelgeuse
Procyon
ORIO
MONOCEROS
Alphard
Sirius
PUPPIS
M-41
CANIS MAJOR
SOUTH

Map Centered on 40 North Latitude



Map by Adolf Schaller

observers, M-44 appears as only a hazy patch of light — but through binoculars, a swarm of hundreds of closely packed, faint stars comes into focus. The cluster is about 400 million years old — very young by astronomical standards — and lies 500 light-years away.

The ancients often referred to M-44 as Praesepe, and used it as a sort of starry barometer. The Roman author Pliny wrote in 50 A.D., "If Praesepe is not visible in a clear sky it is a presage of a violent storm." Three centuries earlier a Greek botanist first explained how condensation in the atmosphere would block out M-44's faint light and warn of an approaching storm.

Continuing along the imaginary line drawn from Capella through Pollux we next reach Hydra, still lurking in the sky after its ancient duel with Hercules. A grouping of seven faint third and fourth magnitude stars denotes the monster's head while a sinuous path of dim stars stretches his slinky body across 100 degrees of sky — from Canis Major to Libra (still below the horizon at this time of year).

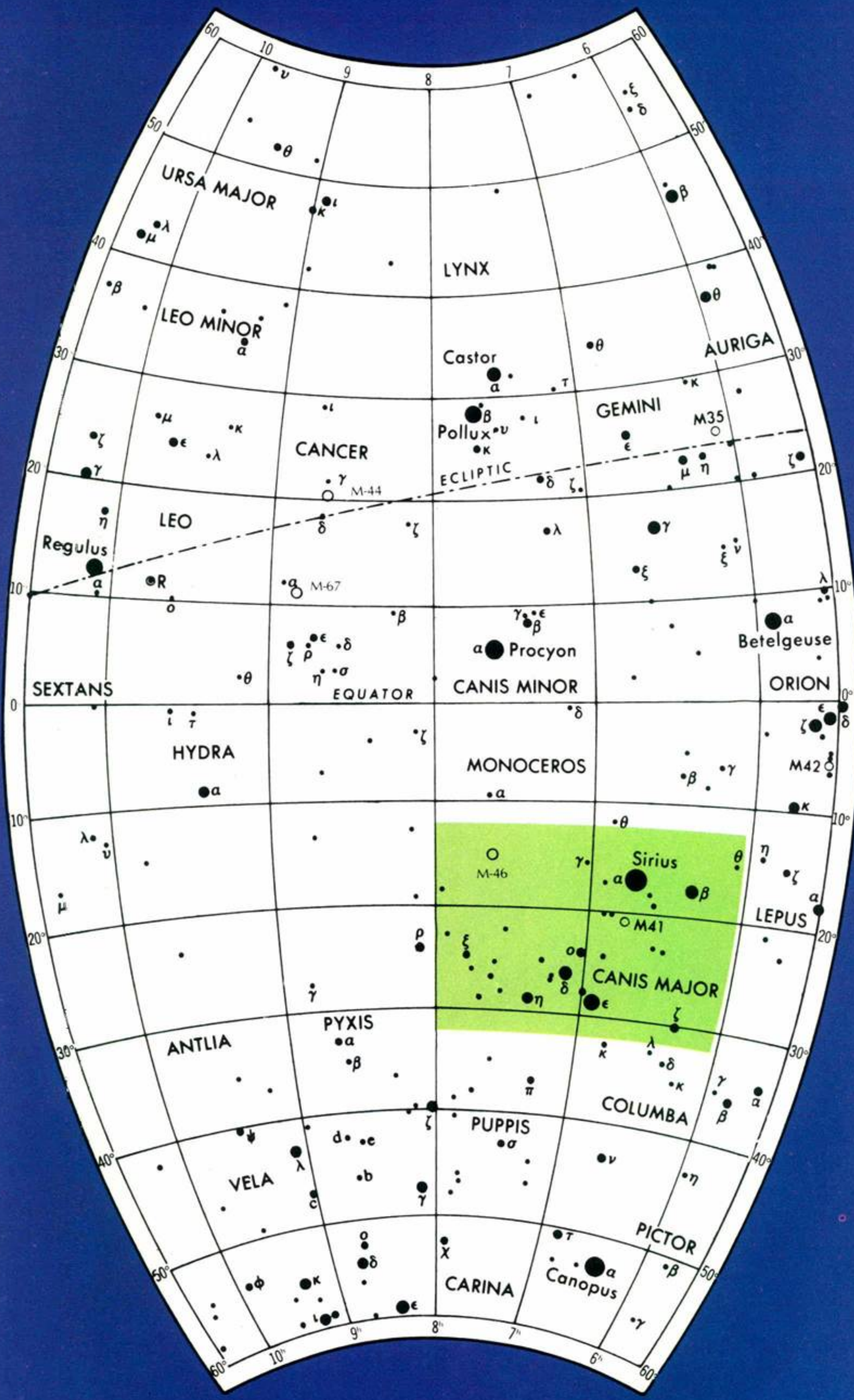
In its battle with Hercules, Hydra actually had nine heads — one being immortal. However, the other eight heads were almost as good as immortal since every time Hercules chopped one head off two more would instantly grow in its place. The warrior finally used a hot iron to seal the neck shut after severing each head — thus preventing any more magical regeneration. Although the tale ends with Hercules burying the monster's immortal head under a rock, Hydra retains a truly immortal head fixed into a star pattern.

Only one bright star shines along the serpent's body — second magnitude Alphard which has an orange-red color. Alphard comes from the Arabic Al Fard al Shuja — appropriately meaning "the solitary one in the serpent".

Elusive Hydra is no match for the brightest constellation near the southern horizon — Canis Major, the great dog. Roughly I-shaped, Canis Major reminded some cultures of a dog standing on its hind feet preparing to spring after Lepus the hare (to the right of the dog) — or perhaps just waiting for Orion to toss a "milk bone".

Within Canis Major, Sirius blazes blue-white at -1.4 magnitude. As the night's most brilliant star, it's no surprise that Sirius drew the attention of many ancient civilizations. Early Romans were convinced that when Sirius shared the sky with the summer sun, their combined energy produced hot summer days (or dog days). Meanwhile, across the Mediterranean, Egyptians worshipped Sirius' early morning summer appearance as a signal that the annual Nile flooding would soon refertilize their land with rich silt. Temples built to Sirius were oriented such that in mid-July, the star's light would shine onto each temple's inner altar.

Following a path from Orion through Canis Major brings us next to the obscure constellation


URSA MAJOR
LYNX
LEO MINOR
AURIGA
Castor
GEMINI
M35
Pollux
CANCER
ECLIPTIC
M-44
LEO
Regulus
R
M-67
Procyon
Betelgeuse
SEXTANS
EQUATOR
CANIS MINOR
ORION
HYDRA
MONOCEROS
M42
M-46
Sirius
M41
LEPUS
CANIS MAJOR
ANTLIA
PYXIS
COLUMBA
PUPPIS
VELA
PICTOR
CARINA
Canopus
60
50
40
30
20
10
0
10
9
8
7
6
10ʰ
9ʰ
8ʰ
7ʰ
6ʰ

Star Magnitudes

●	●	●	●	●	●	●	●	•	·
—1	0	1	1½	2	2½	3	3½	4	5

○ Cluster or Nebula

⊙ Variable Star

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α	Alpha	η	Eta	ν	Nu	τ	Tau
β	Beta	θ	Theta	ξ	Xi	υ	Upsilon
γ	Gamma	ι	Iota	ο	Omicron	φ	Phi
δ	Delta	κ	Kappa	π	Pi	χ	Chi
ε	Epsilon	λ	Lambda	ρ	Rho	ψ	Psi
ζ	Zeta	μ	Mu	σ	Sigma	ω	Omega

Map from **Guideposts to the Stars**; reprinted permission of MacMillan Publishing Co., ©1972 by Leslie C. Peltier.

Puppis, the stern of the great ship Argo. Originally the huge southern hemisphere constellation Argo Navis (representing the famed vessel of the ancient Greek adventurers Jason and the Argonauts) contained more than 800 naked eye stars. For simplicity, it was later chopped up into three parts — keel, stern and sail — and a navy surplus store-full of accessories were added — including a clock, pump and compass.

From the northern hemisphere Argo looks more like the Titanic, with Puppis poking above the southern horizon like the stern of a sinking ship. Two faint stars to the left of the great dog's hindquarters are all we ever easily see of this magnificent vessel.

Close-Up on the Canis Major/Puppis Region

Normally a bright star attracts attention to a constellation. What would Lyra be without Vega, or Cygnus without Deneb? In each case the constellation is very clearly identified with its bright star. But such an association generally is not applicable to Sirius, the night sky's brightest star. Actually the reverse seems to have happened. Sirius' dazzling brilliance has tended to overshadow what is otherwise the third brightest constellation visible from midnorthern latitudes.

The statistic that Canis Major is the third brightest constellation in our skies will probably come as a surprise to most readers. To judge this "brightness factor" we used the number of stars equal to or above magnitude 3.0 contained in a constellation. Scorpius is by far the champion in this respect with 13 stars above that level; Orion is second with eight, and Canis Major is tied with Sagittarius for third place with seven. (Actually Centaurus is in second place with nine stars equal to or above magnitude 3.0 — but it doesn't qualify here since it is not visible from midnorthern latitudes.)

Admittedly our criterion of selecting stars 3.0 magnitude and brighter is somewhat arbitrary but it does give an idea of the brilliance of this constellation which is often passed over. In the Eyepiece Impressions section below, several objects in Canis Major and nearby Puppis will certainly provide the telescope user with reason to stop and linger in this part of the sky.

To the unaided eye, the stars of Canis Major and Puppis constitute a slightly less dazzling extension of the brilliant Orion region. Many of the stars in these two constellations are about the same distance as the superbrilliant blue-white luminaries of Orion and are part of an extremely rich zone of the Milky Way galaxy.

When you look at some of the stars of Canis Major, you are looking at the most distant, medium bright stars visible. Delta (δ), sometimes called Wessen, is about the luminosity of Rigel in Orion but is at least 2,000 light-years distant. Even farther away is Eta at 2,700 light-years — also about the same brightness as Rigel. We mentioned last month that Rigel, having 55,000 times the sun's luminosity, is probably the brightest star in this part of the galaxy. These two rivals to that title may indeed be brighter but their distances are not known with enough accuracy to define which of the stars holds the crown. There are a handful of other stars which are in the same category.

Viewed from our solar system, Sirius just happens to be in front of this rich assemblage of brilliant and distant stars. If we were to look at Sirius from Alpha Centauri, it would appear to be quite close to Betelgeuse in the constellation Orion. Thus, from Alpha Centauri, Orion would be without doubt the most dazzling constellation in the sky, far exceeding its already impressive appearance from Earth. The rest of the constellation of Canis Major would be virtually unchanged because, apart from Sirius, we are looking at extremely distant stars. Sirius is a remarkable neighbor in both its brightness (27 times the sun's) and its strange companion star which is described below.

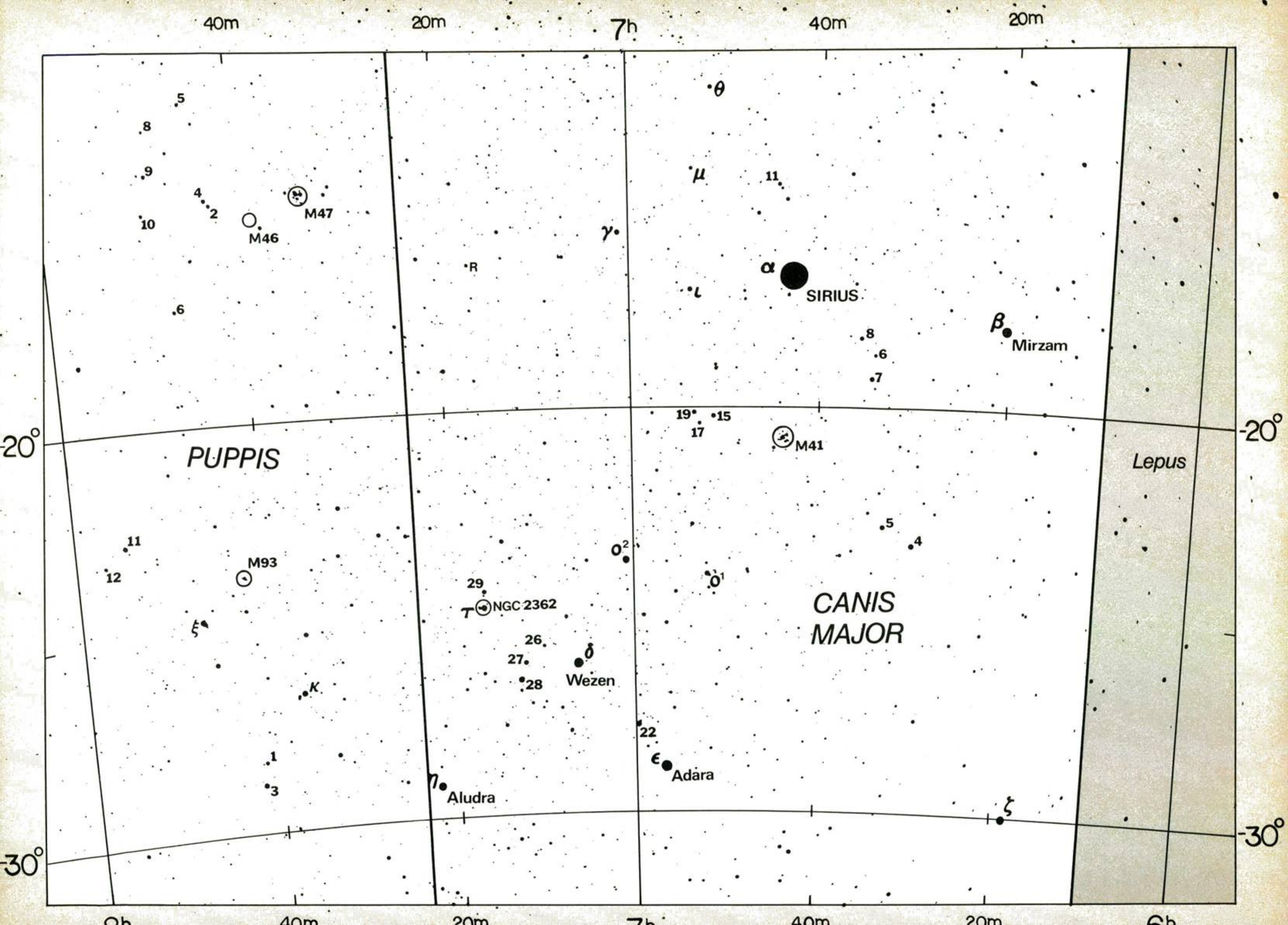
Embedded in the Milky Way, Puppis — Canis Major's neighbor — is rich in interesting telescopic objects but because of its low altitude (as viewed from at least the northern U.S.), the constellation has received scant attention from telescope users. We mentioned that the other objects in Canis Major were sometimes neglected because of Sirius' dominance, but Puppis is ignored far more than Canis Major ever was. As usual we have selected a half dozen or so striking objects from our close-up area to be examined in detail so let's find out what they are.

Eyepiece Impressions

Sirius

Trailing Orion up the southeastern sky these winter evenings is his eternally faithful companion Sirius, the so-called Dog Star in Canis Major. Shining at magnitude -1.4, this blazing blue-white beacon is the brightest star in the entire sky and, as mentioned above, one of our nearest neighbors in space.

Sirius is also one of the most studied binary stars in the sky. Its elusive eighth magnitude companion is the best known representative of that strange class of aged suns known as white dwarfs.


40m
20m
7h
40m
20m
-20°
-30°
θ
μ
11
γ
α
SIRIUS
ι
β
Mirzam
8
6
7
19
15
17
M41
Lepus
5
4
O²
O¹
CANIS MAJOR
29
τ
NGC 2362
26
27
28
δ
Wezen
22
ε
Adara
η
Aludra
ζ
5
8
9
4
2
10
M47
M46
R
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PUPPIS
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12
M93
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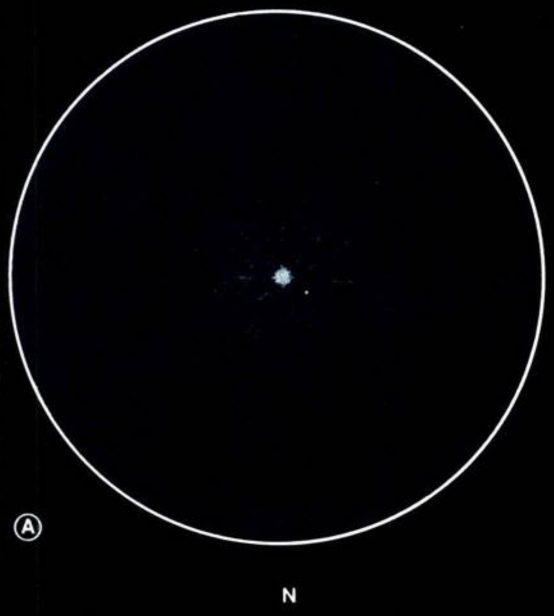
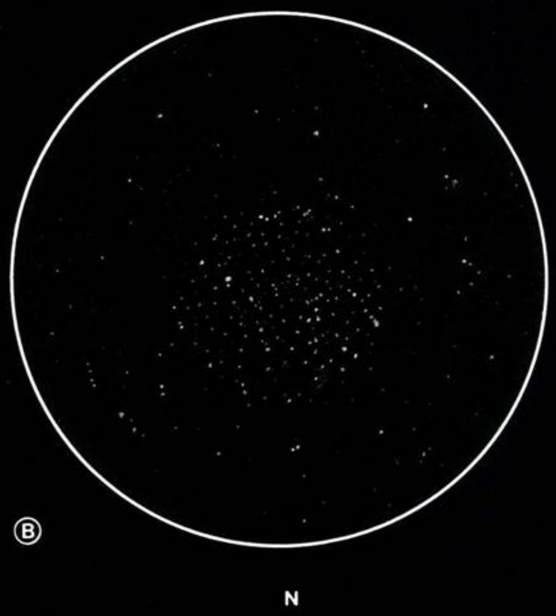
κ
1
3
40m
20m
40m
20m





Ⓐ

Sirius blazes like a dazzling diamond in any telescope. This rendering captures its appearance at 145 power in a 13 inch refractor — a large enough instrument to easily show the eighth magnitude companion, now at its maximum separation of 11 seconds of arc. By 1995, the companion will be only three seconds from Sirius and virtually invisible in any telescope.

Ⓑ

The dozens of stars in M-46 are neatly enclosed in this view through an eight inch reflector at 80 power. The field of view (approximately 40 minutes of arc wide) can be compared to the photo on page 61 where the donut shaped planetary nebula appears red — not pale white, as seen visually.

Ⓒ

Three views of Kappa Puppis are shown together in the same field of view for comparison. The views are through a three inch refractor at 20 power (top), 45 power and 150 power (bottom). The two components of this double star system appear to touch each other at low power but are clearly separated with higher magnification. At high power under conditions of good seeing, a good quality telescope will display the diffraction rings shown here.

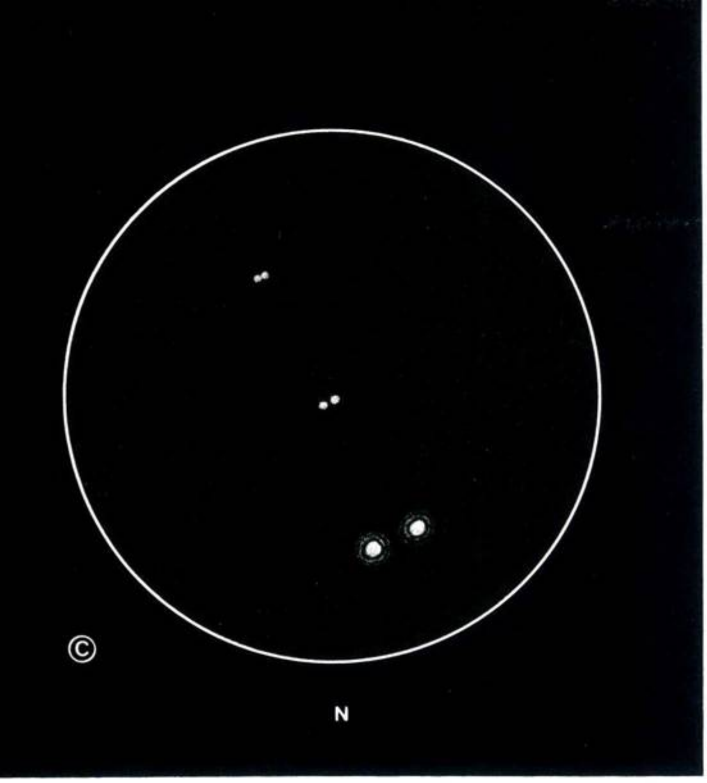
Completing a circuit of its primary every 50 years, the companion is presently at its widest separation at a distance of 11 seconds of arc. This pygmy star has been glimpsed in telescopes as small as a six inch and is easily seen in a 12 inch when seeing conditions (image steadiness) are good. At such times an eight inch reflector should reveal the star with patient watching.

The vast difference in brightness between Sirius and its companion (a ratio of 10,000 to 1), combined with the relatively low altitude of the pair for northern observers and the often poor seeing of winter, make this object a real test of instrument, site and observer. R. W. Burnham, the famous double star observer, once said of this pair: "An object glass of six inches one night will show the companion to Sirius perfectly; on the next night, just as good in every respect, so far as one can tell with the unaided eye, the largest telescope in the world will show no more trace of the small star than if it has been blotted out of existence."

Even if your telescope won't reveal the companion, Sirius itself is a wondrous sight of light and color in even the most modest of instruments. Its mere aspect in some telescopes is enough to suggest that the stars are indeed other suns. Using his homemade 48 inch reflector in England, Sir William Herschel recorded the following classic observation of this great star: "The appearance of Sirius announced itself... and came on by degrees, increasing in brightness, till this brilliant star at last entered the field of view of the telescope, with all the splendor of the rising sun, and forced me to take the eye from that beautiful sight."

Another famous observer of the past was William Lassell, who like Herschel used a 48 inch metal mirror reflector. He wrote: "Sirius is an object I would challenge anyone to see as I see it, for the first time, without an involuntary exclamation of wonder! With 260 magnifications it is an incandescent diamond, which I cannot describe.... The pencil of light transmitted through the eyepiece from this star, cast a brilliant spot on the wall of the observatory sufficient forcibly to attract my notice, without being at all prepared for it...."

Despite the difference in size, a modern amateur's telescope will show these impressions to be still valid — especially if the eye has been well dark-adapted before viewing the star. For a really striking sight, try observing Sirius with the eyepiece extended outside of focus. If the seeing is



Sketches by James Mullaney

really poor, you will behold an amazing multicolored flashing gem.

M-41

This scattered open cluster of stars located about four degrees south of Sirius is visible to the unaided eye on dark winter nights. It is one of the few star clusters that were known to the Greeks. Aristotle mentioned it in his writings (in about 325 B.C.), describing it as a "cloudy spot". The cluster's true nature is obvious in binoculars and small telescopes. The brighter stars are arranged in distinctive curves or loops and near the center, as is frequently the case with open clusters, there is a reddish-orange sun. (See photo on page 60.)

This stellar family contains about 50 easily seen members spread over an area the apparent size of the full moon. Thus M-41 is not particularly rich, requiring low powers and a wide field of view for an effective impression. A three or four inch scope at 45 power does nicely. Here, as with other clusters at low sky declinations, those infrequent nights of both good seeing and transparency should be sought for a really good view. There is, however, one advantage to low altitude observing during poor conditions — clusters like M-41 will show a glittering aspect rarely seen in objects high in the sky.

The cluster is approximately 20 light-years in diameter and about 2,200 light-years distant.

NGC-2362

Even lower in the sky than M-41 is the neglected open cluster NGC-2362 — easily located surrounding the fourth magnitude star Tau (τ) Canis Majoris. Here are some 40 stars in a small area only six minutes of arc in diameter. Centered on Tau, the stars are rather faint — requiring a six or eight inch telescope for a worthwhile view. Larger instruments show this object as a distant nest of jewels containing a brilliant centerpiece.

Tau seems to be a true member of the cluster and is one of the intrinsically brightest stars known. It consists of two stars (appearing single in the telescope), each nearly as powerful as Rigel. The stars' brightness is muted by the cluster's 5,000 light-year distance.

Kappa (κ) Puppis

Just five degrees east of NGC-2362 lies another neglected southern object — the fourth magnitude double star Kappa Puppis. Greatly resembling the well-known northern double Gamma (γ) Arietis, this striking pair consists of two equally matched (4.5 and 4.6 magnitude) white stars that are 10 seconds apart. A 2.4 inch or 3 inch refractor at 45 power splits the pair nicely. Lower magnifications and poor seeing will often combine to give an interesting view of the two stars nearly touching each other and at times merging together into an egg shaped image!

M-46

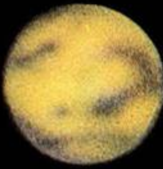
Moving 12 degrees directly north of Kappa Puppis — about 2/3 of the way along a line joining this star with fourth magnitude Alpha (α) Monocerotis — we find the unique open cluster M-46. This beautiful spherical cloud of faint stars contains well over 100 members in an area 24 minutes across. Most of its stars are of the same brightness, giving this cluster a uniform appearance and making for a fine sight in a four inch telescope.

Adding greatly to the interest of this cluster is the dim planetary nebula near its northern edge known as NGC-2438. This 11th magnitude object is 68 seconds of arc in diameter and looks much like a smaller and fainter version of the famous Ring nebula in Lyra. It is easily seen in a 10 inch reflector at 150 power with good transparency and can be glimpsed in six and eight inch instruments. A well dark-adapted eye and the use of averted (side) vision will greatly aid in its detection.

Lassell described it as "an astonishing and interesting object". However, this unusual combination is only the result of a remarkable coincidence — the cluster and nebula differ greatly in their space velocities and are therefore not associated; they simply happen to lie in the same line of sight. The only other known case of such a combination among prominent deep-sky objects is the globular cluster M-15 in Pegasus, which contains a very faint planetary. This fact is all the more remarkable when we note that at least one cluster member can be seen shining through the hole in the ring, just like a typical planetary nebula central star!

M-46 itself lies nearly 6,000 light-years from us amidst the glitter of the winter Milky Way. An observer properly positioned within the cluster, looking across this vast gulf toward us, may see a ghostly smoke ring in the center of which appears a faint yellow star — our sun!

Planet Finder



Ⓒ Cer

March	1	15
R.A.	0^h28^m	0^h47
Dec.	-5°12'	-2°47
Mag.	+9.3	+9.3

Ⓐ Mercury

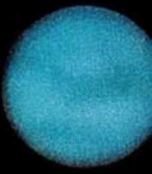
March	1
R.A.	21^h02^m
Dec.	-16°23'
Mag.	+0.4

Ⓑ Mercury

March	15
R.A.	22^h03^m
Dec.	-13°41'
Mag.	+0.2

Ⓜ Mars

March	1	15
R.A.	20^h05^m	20^h46^m
Dec.	-21°13'	-18°51'
Mag.	+1.4	+1.4



Ⓝ Neptu

March	15
R.A.	16^h4
Dec.	-20°3
Mag.	+7.7

SUN

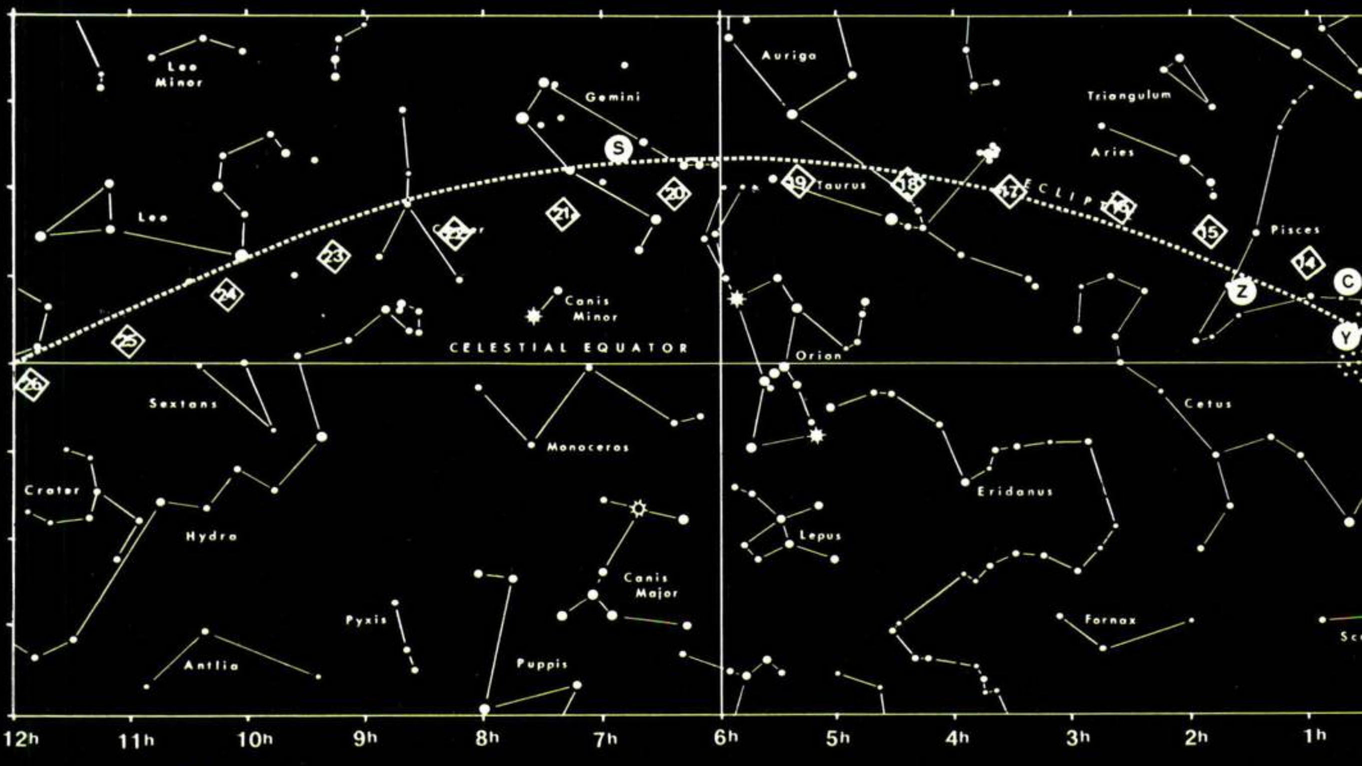
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

March	1	15
R.A.	6^h52^m	6^h51^m
Dec.	+22°36'	+22°39'
Mag.	+0.1	+0.2

Ⓤ Uranus

March	15
R.A.	14^h00^m
Dec.	-11°36'
Mag.	+5.7



Leo Minor
Leo
Gemini
Cancer
Canis Minor
CELESTIAL EQUATOR
Sextans
Monoceros
Crater
Hydra
Canis Major
Pyxis
Antlia
Puppis
Auriga
Taurus
Orion
Lepus
Eridanus
Fornax
Triangulum
Aries
ECLIP
Pisces
Cetus
Sc
S
Z
C
Y
26
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18
17
16
15
14
12h
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4h
3h
2h
1h

Map by Raymond G. Coutchie

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

March 1975

Vesta

larch	1	15
.A.	20h50m	21h19m
ec.	-18°55'	-17°19'
lag.	+8.2	+8.2

Ⓙ Jupiter

March	1	15
R.A.	23h46m	23h59m
Dec.	-2°35'	-1°14'
Mag.	-1.6	-1.6

Ⓨ Venus

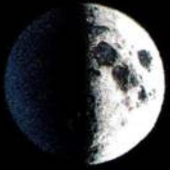
March	1
R.A.	0h27m
Dec.	+1°56'
Mag.	-3.4

Ⓩ Venus

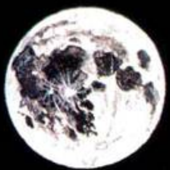
March	15
R.A.	1h29m
Dec.	+9°05'
Mag.	-3.4

Pluto

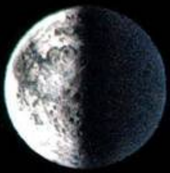
arch	15
.A.	12h56m
ec.	+12°46'
ag.	+14



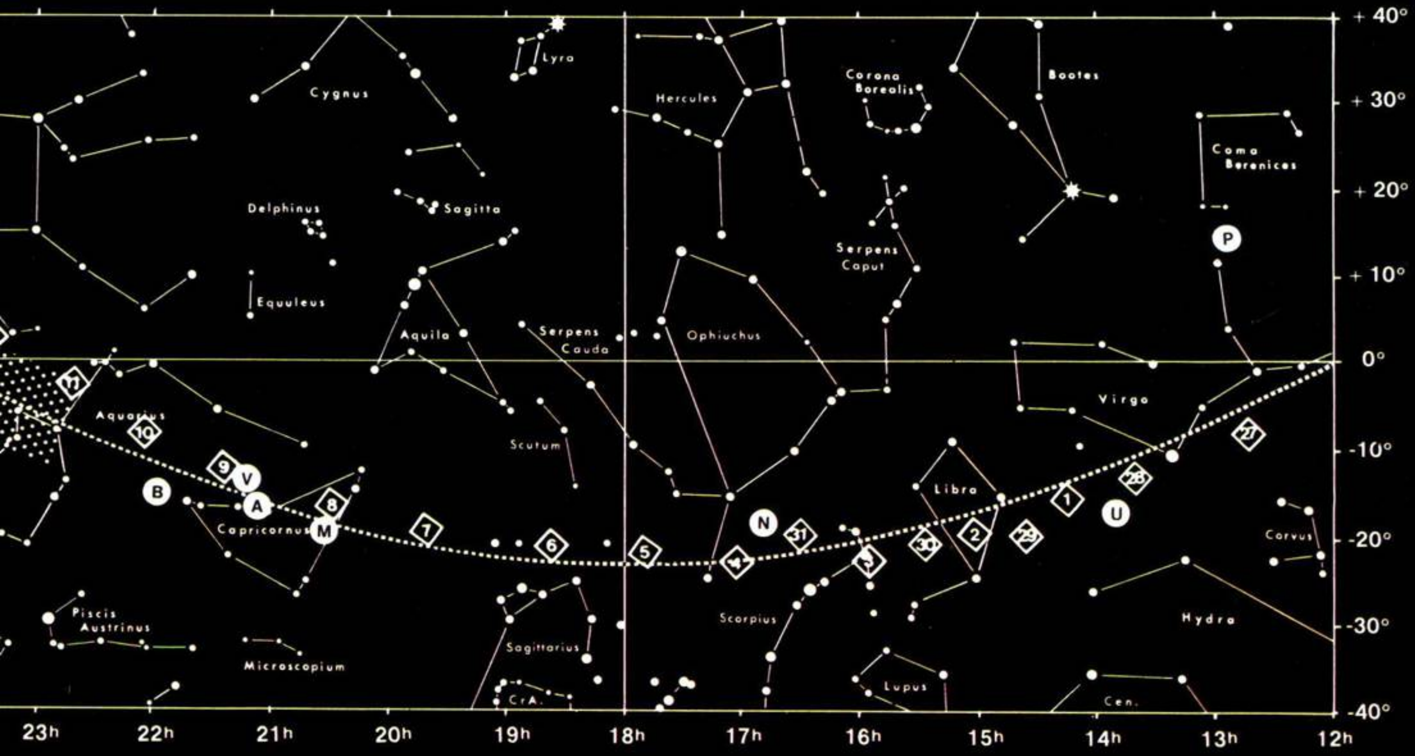
First Quarter
March 20



Full Moon
March 27



Last Quarter
March 4


+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h
Cygnus
Lyra
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Capricornus
Corvus
Scorpius
Hydra
Piscis Austrinus
Sagittarius
Microscopium
Lupus
CrA.
Cen.
P
B
V
A
M
N
U
J
2
4
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28
29
30
31

Artwork by Victor Costanzo

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

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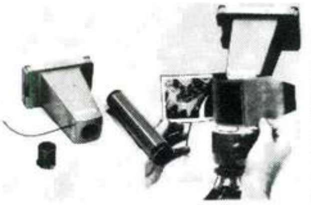

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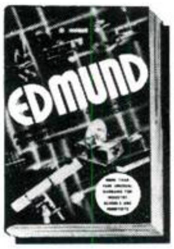

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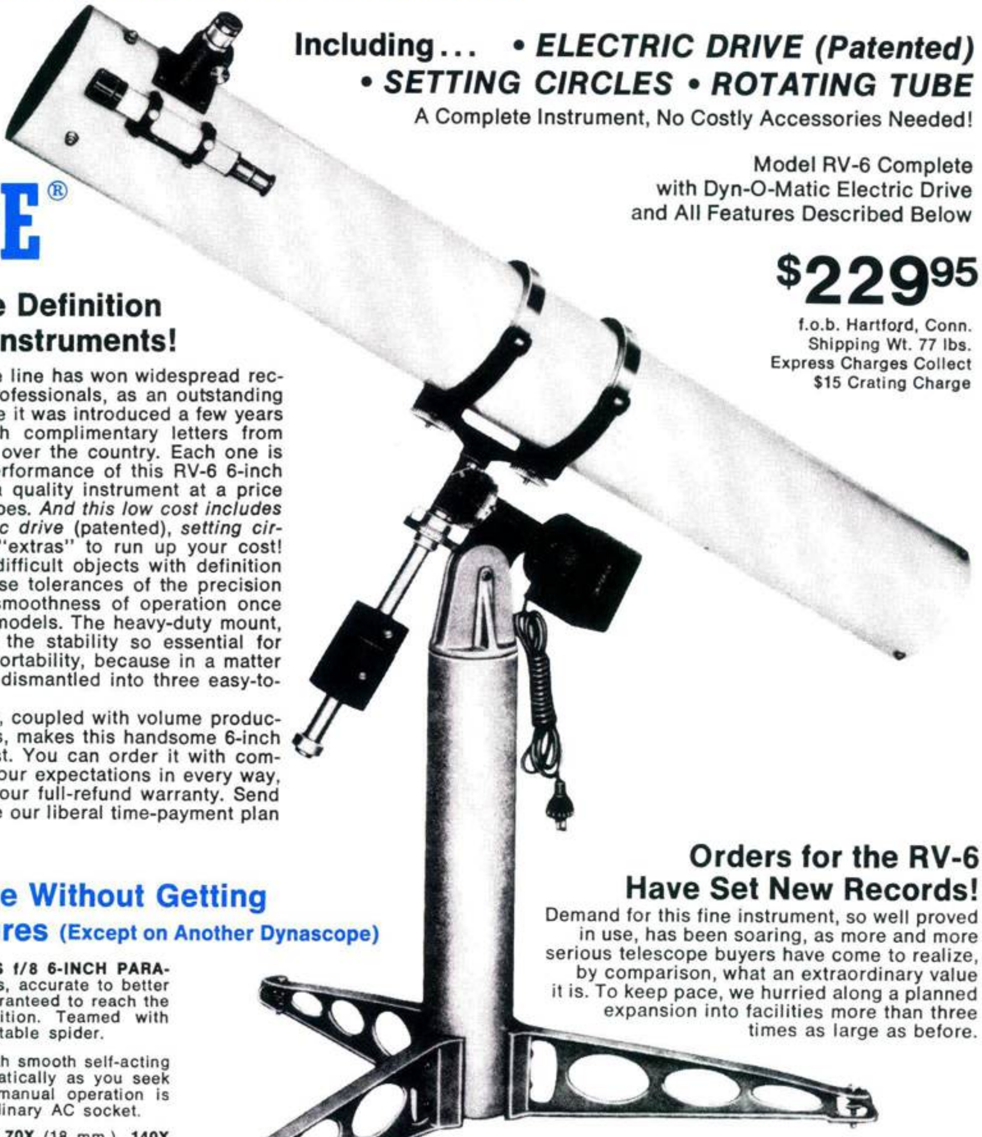

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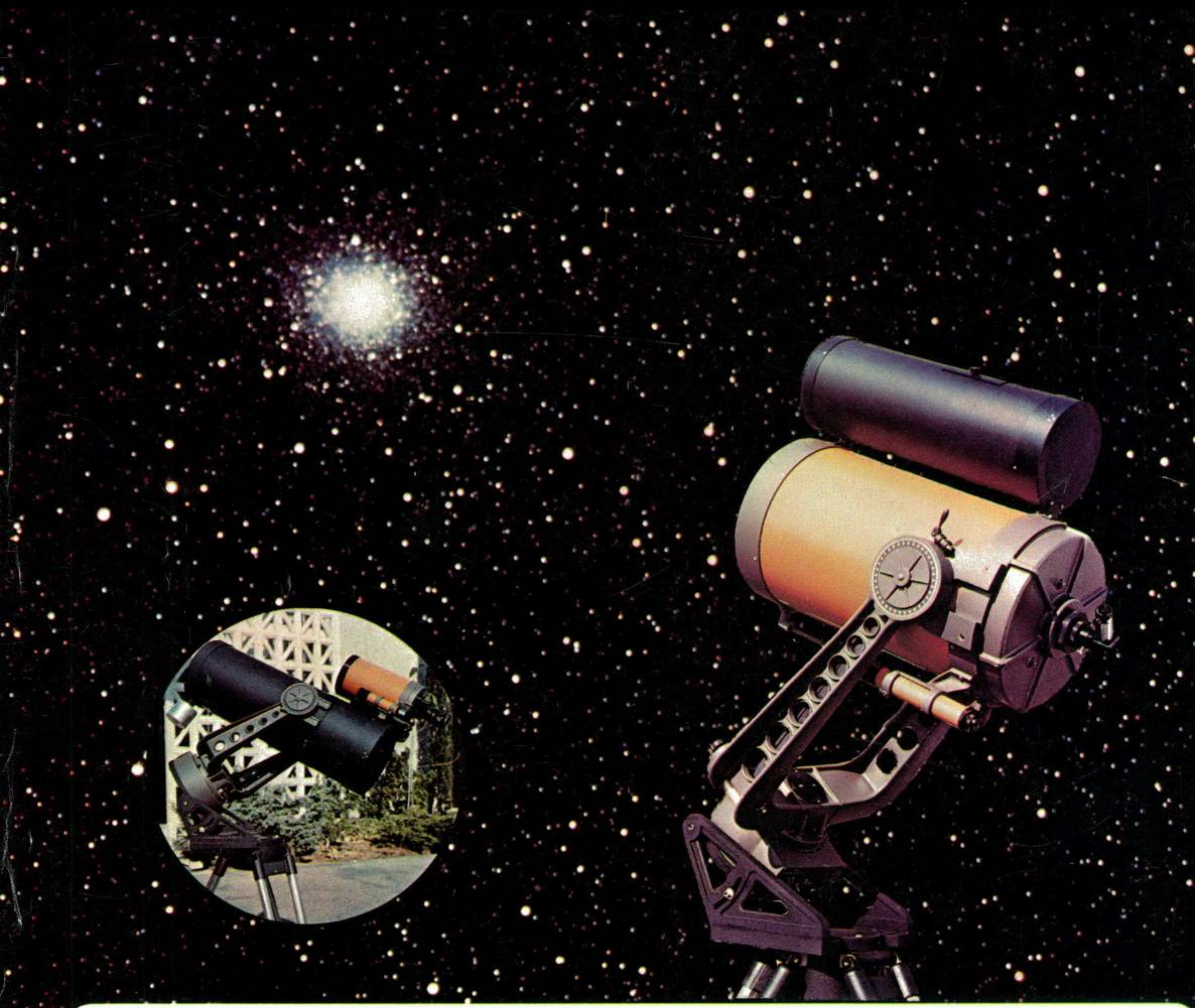

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